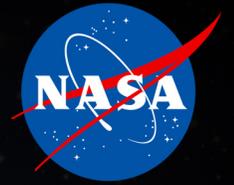


National Aeronautics and Space Administration



HUMAN RESEARCH PROGRAM

2010 Annual Report



explore life

2010 WAS A YEAR OF SOLID PERFORMANCE FOR THE HUMAN RESEARCH PROGRAM

in spite of major changes in NASA's strategic direction for Human Spaceflight. Last year, the Program completed the final steps in solidifying the management foundation, and in 2010 we achieved exceptional performance from all elements of the research and technology portfolio. We transitioned from creating building blocks to full execution of the management tools for an applied research and technology program. As a team, we continue to deliver the answers and technologies that enable human exploration of space. While the Agency awaits strategic direction for human spaceflight, the Program is well positioned and critically important to helping the Agency achieve its goals.

The many outstanding products described in this report were intended to support design of the Constellation Program's vehicles, missions, and architectures. However, it becomes easy to see that the advances in our risk-based program are entirely applicable to all human exploration missions, including Near-Earth asteroids, Lagrange Points, and Mars fly-by. The application of the Human Research Roadmap to new missions under study, makes it very clear that the knowledge, models, and evidence framing the Human Research Program are key drivers to all exploration missions.

With the extension of the International Space Station (ISS) to 2020, the Human Research Program is well positioned to increase the use of this valuable international laboratory to understand and solve many of the issues that confront humans on exploration missions. Our work with exercise, nutrition, lighting, and other areas will make exploration missions healthier, safer, and more productive.

The Program is making extensive use of the ISS to address the issues of maintaining human health and performance during and after long-duration spaceflight. We conducted an average of ten experiments per increment to further our solutions to mitigate bone loss and decreased cardiovascular capacity as well as track

changes in spacecraft microbes and human immunological function. Human research is one of the most active U.S. research areas on the ISS.

The emergence of persistent changes to ISS crew member's vision and intracranial pressures have unmasked a problem that must be addressed through research and clinical monitoring. These pressure effects cause permanent changes to the eye and vision and hold the prospect of increased lifetime risks due to chronically elevated intracranial pressures. The Human Research Program is working diligently with flight surgeons to develop a research plan that will illuminate the causal factors of these changes and proceed to find a remedy. The consequences of this problem would, if left unchecked, inhibit missions longer than six months in space.

“ We continue to deliver the **ANSWERS** and **TECHNOLOGIES** that **ENABLE** human **EXPLORATION** of space. ”

We continued to engage the U.S. research and international space life sciences communities through three research solicitations, a Small Business Innovative Research solicitation, innovation challenges, workshops, and working groups. In April 2011, the HRP and the National Space Biomedical Research Institute (NSBRI) will be hosting the 18th International Academy of Astronautics (IAA) Humans in Space Symposium to be held in Houston.

Message from the Program Manager

This premier event will also celebrate the 50th anniversary of Yuri Gagarin's flight and the 30th anniversary of the Space Shuttle.

We expanded our education and outreach activities, creating an exciting international program involving nine nations. "Mission X: Train Like an Astronaut" is an international fitness challenge that engages students in nutrition, exercise, and healthy lifestyle choices using a space theme and the ISS crews.

The Human Research Program will continue to leverage our organizing framework, produce research and technology results, and stay focused on the most significant problems to ensure a highly successful human space exploration program.



A handwritten signature in black ink that reads "Dennis J. Grounds". The signature is written in a cursive, flowing style.

Dennis J. Grounds
Program Manager

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Background

Crew health and performance are critical to successful human exploration beyond low Earth orbit. Risks to health and performance include physiologic effects from radiation, hypogravity, and planetary environments, as well as unique challenges in medical treatment, human factors, and support of behavioral health. The scientists and engineers of the Human Research Program (HRP) investigate and reduce the greatest risks to human health and performance, and provide essential countermeasures and technologies for human space exploration.

In its fifth year of operation, the HRP continued to establish its management architecture of evidence, risks, gaps, tasks, and deliverables. Products were delivered to support the preliminary design of the Constellation Program vehicles. Experiments continued on the International Space Station (ISS) and in laboratory environments on the ground in analog environments that have features similar to those of spaceflight. Data from these experiments furthered our understanding of how the space environment affects the human system. These research results contributed to scientific knowledge and technology developments that address the human health and performance risks.

As shown in this report, the HRP made significant progress toward reducing risks to crew health and performance and developing medical care and countermeasure systems for space exploration missions.

Goal and Objectives

The goal of the HRP is to provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration. These are the specific objectives of the HRP:

1. Develop capabilities, necessary countermeasures, and technologies in support of human space exploration, focusing on mitigating the highest risks to crew health and performance. Enable the definition and improvement of human spaceflight medical, environmental and human factors standards.
2. Develop technologies that serve to reduce medical and environmental risks, to reduce human systems resource requirements (mass, volume, power, data, etc.) and to ensure effective human-system integration across exploration mission systems.

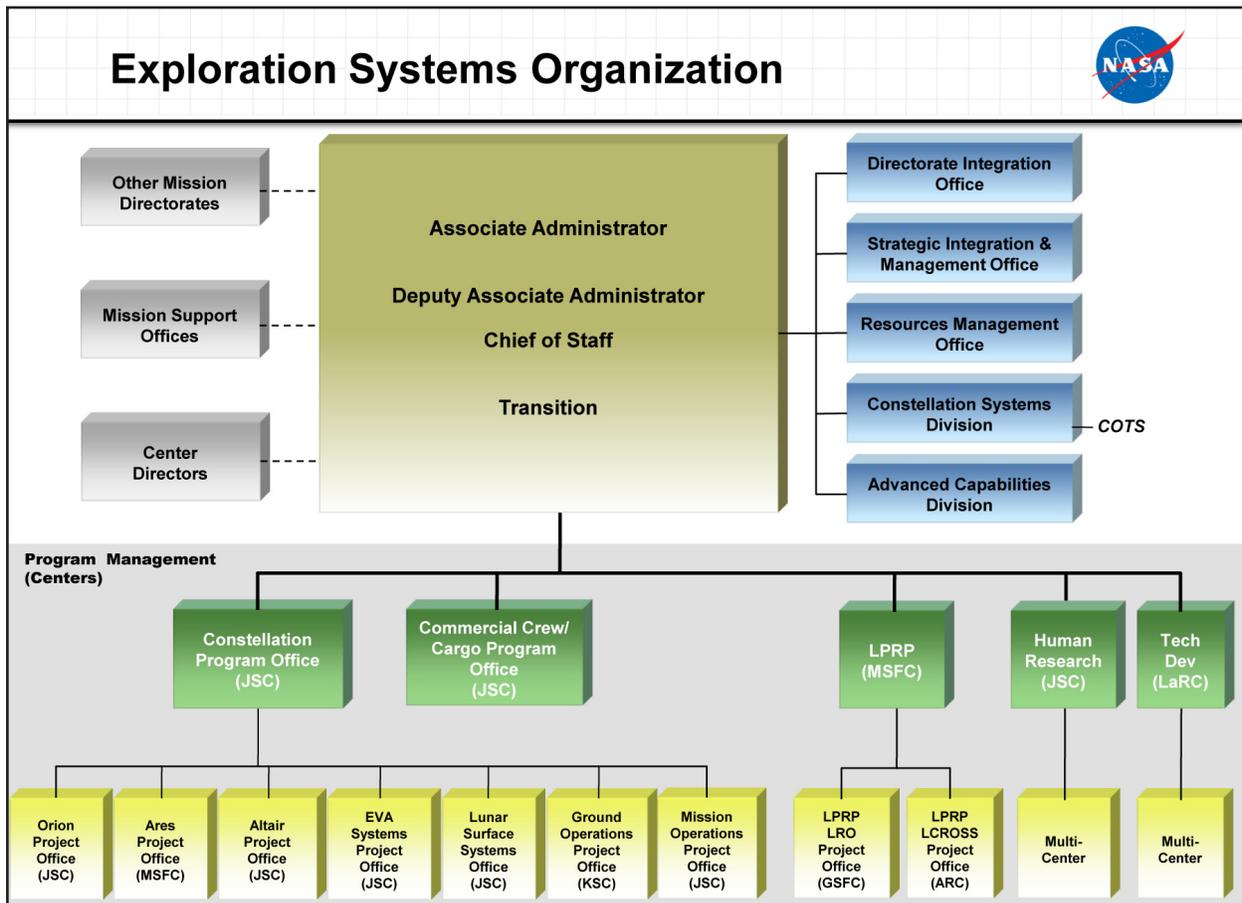
3. Ensure maintenance of Agency core competencies necessary to enable risk reduction in the following areas: space medicine, physiological and behavioral effects of long duration spaceflight on the human body, space environmental effects, including radiation, on human health and performance and space human factors.

Program Organization

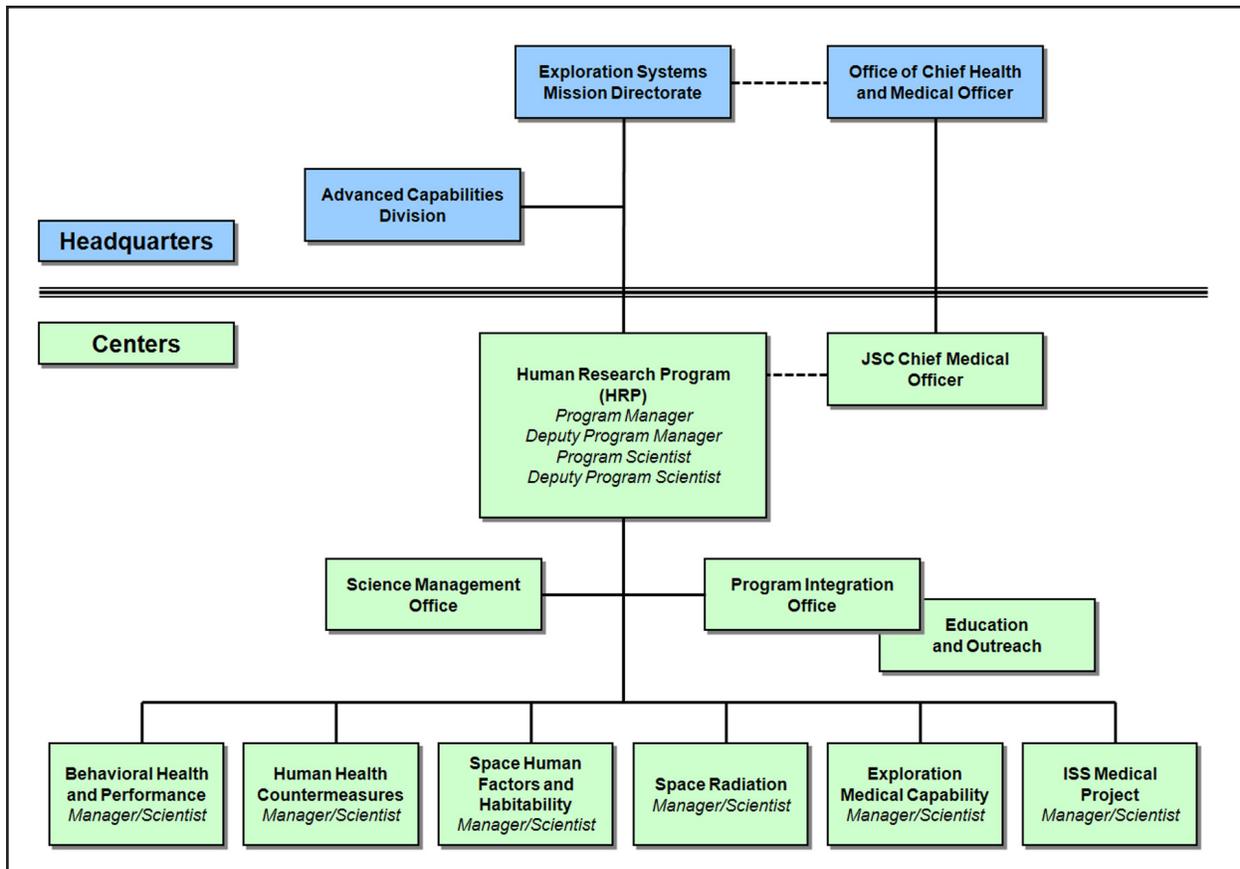
The HRP conducts research and develops technology that enables NASA's Office of the Chief Health and Medical Officer (OCHMO) to develop or modify NASA-wide human health and performance standards. HRP provides the Exploration Systems Mission Directorate (ESMD) with methods of meeting those standards in the design, development,

and operation of technological systems for exploration missions. The HRP resides within the ESMD. Management of the HRP is located at the Johnson Space Center.

The HRP's organization is designed to support and accomplish the goals of the ESMD and the OCHMO. The Program Manager and Deputy Program Manager lead all aspects of the HRP. The Program Scientist and Deputy Scientist lead the science management and coordination. Two offices support program and science management and provide integration across the Program. There are six elements that comprise the Program and are focused to accomplish specific goals for investigating and mitigating the highest risks to astronaut health and performance.



2010 Organizational Structure of the Exploration Systems Mission Directorate including the HRP



HRP Organizational Structure

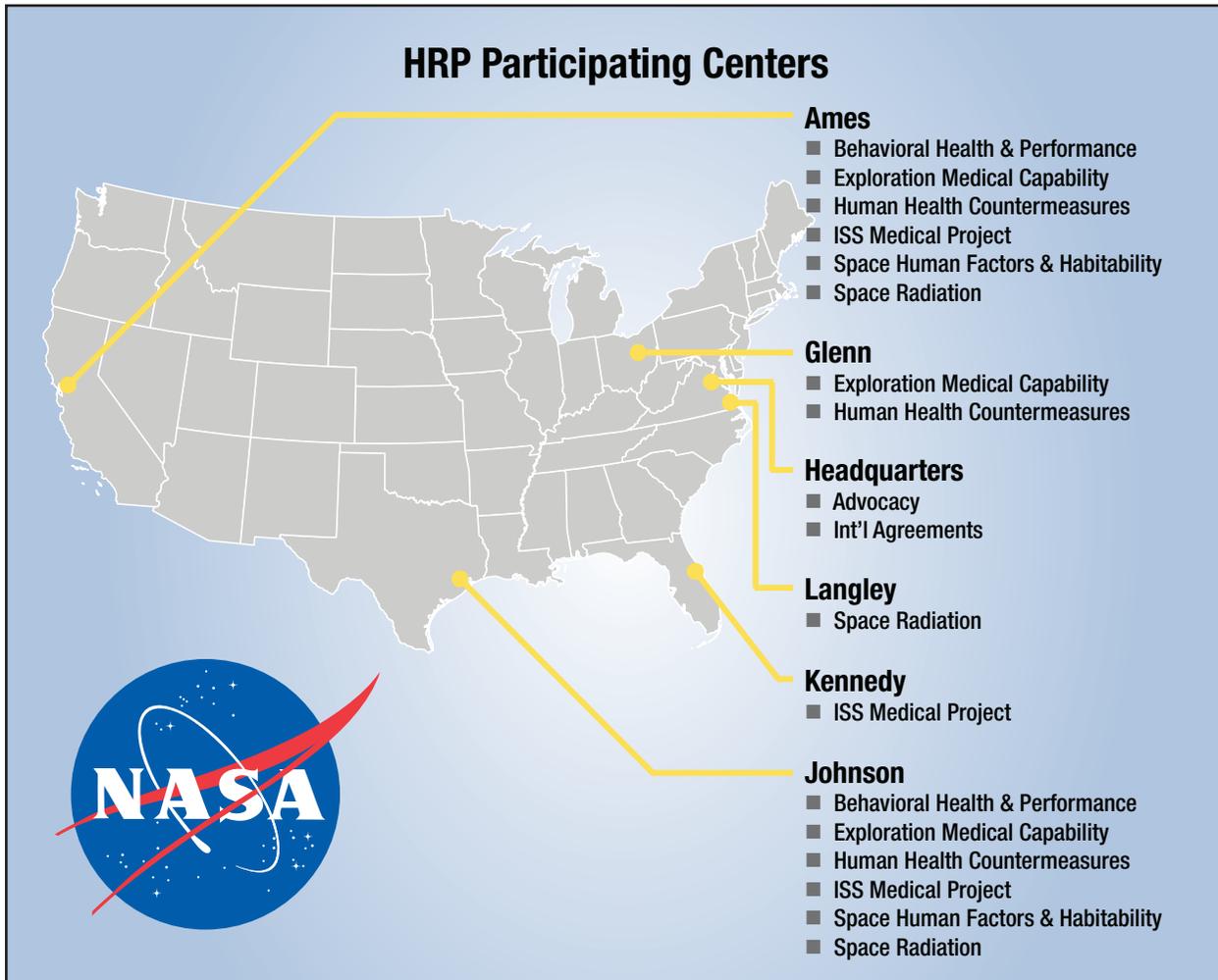
The Science Management Office (SMO) and Program Integration Office (PIO) provide key integration of activities across the HRP in support of the Program Manager, Program Scientist, and all other components of the Program. The SMO maintains scientific integrity of the HRP’s research and reviews and integrates science tasks across the Program, reviews the prioritization and implementation of flight and ground analog tasks, communicates research needs to other NASA programs and cultivates strategic research partnerships with other domestic and international agencies. The PIO provides program planning, integration, and coordination across the HRP. This office ensures close coordination of customer needs and the HRP’s deliverables developed to meet those needs.

Six subject areas or elements comprise the HRP: International Space Station Medical Project, Space

Radiation, Human Health Countermeasures, Exploration Medical Capability, Space Human Factors and Habitability, and Behavioral Health and Performance. These elements provide the HRP’s knowledge and capabilities to conduct research to address the human health and performance risks of spaceflight, and they advance the readiness levels of technology and countermeasures to the point where they can be transferred to the customer programs and organizations. Each element consists of related projects and research tasks focused toward developing products that reduce the highest risks in that area.

Partnerships and Collaborations

The HRP works with universities, hospitals, and federal and international agencies for the purpose of sharing research facilities and multi-user hardware, and for collaboration on research tasks of mutual



interest. The HRP uses bed rest facilities at the University of Texas Medical Branch in Galveston, Texas, to study changes in physiologic function associated with weightlessness. Many of these changes occur in people subjected to bed rest with the head tilted downward at a 6 degree angle.

Facilities at the General Clinical Research Center and the Lerner Research Institute at the Cleveland Clinic/University of Washington support the HRP. These facilities provide bed rest and 6 degree head-down-tilt simulation along with a zero-gravity locomotion simulator, which is a treadmill used by a person lying down such as during bed rest.

The NASA Space Radiation Laboratory at the Department of Energy's Brookhaven National Labora-

tory is used to conduct research using accelerator-based simulation of space radiation. The HRP also uses radiation research facilities at the Loma Linda University Medical Center.

The National Space Biomedical Research Institute (NSBRI), an academic institute funded by the HRP, investigates the physical and psychological challenges of long-duration human spaceflight. Founded in 1997 through a NASA competition, the NSBRI is a nonprofit research consortium that connects the research, technical, and clinical expertise of the biomedical community with the scientific, engineering, and operational expertise of NASA. Additional information about the NSBRI can be found at: www.nsbri.org.

The HRP also maintains collaborative relationships with the ISS International Partners through various working groups. These relationships enhance the research capabilities of all partners and provide synergism of research efforts.

Examples of Partnerships and Collaborative Relationships with Universities, Industries, and Government Agencies

Examples of HRP Partnerships and Collaborations	Benefits to Exploration
National Space Biomedical Research Institute	Academic institute which investigates the challenges of long-duration human spaceflight and bridges the expertise of the biomedical community with the scientific, engineering, and operational expertise of NASA
International Space Life Sciences Working Group (Canada, Japan, Germany, Ukraine, France, and the European Space Agency)	Provides coordination of international development and use of spaceflight and ground research facilities by identifying mutual interests and compatibilities, enhancing communication, and encouraging a unified effort among participating space life sciences communities around the world
US-Russian Joint Working Group	Enhances research capabilities and provides synergy in operations and optimal use of the ISS
National Institutes of Health, Department of Energy, Centers for Disease Control and Prevention, Department of Agriculture, Department of Defense	State-of-the-art research facilities, research activities, and technology development of mutual interest
General Clinical Research Center and the Lerner Research Institute at the Cleveland Clinic/University of Washington	Provides facilities for bed rest and 6-degree head-down-tilt simulation along with a zero-gravity locomotion simulator in support of HRP research
NASA Extreme Environment Mission Operations at the Aquarius Undersea Habitat and other analog environments such as Antarctica and Devon Island	Research performed in analog environments in the areas of physiologic adaptation, medical technology, and behavioral health and performance
University of Texas Medical Branch, Galveston, TX	Provides bed rest facilities to study changes in physiologic function associated with weightlessness
Department of Energy - Brookhaven National Laboratory	State-of-the-art facility conducts research using accelerator-based simulation of space radiation
Loma Linda University	Space radiation research and facilities
European Union in Radiobiology Research Program	Space radiation research
International Council of Radiation Protection	Recommendations for radiation protection in space
Massachusetts Institute of Technology Man-Vehicle Laboratory	Working to define the role of the human in complex space systems



Examples of HRP Partnerships and Collaborations	Benefits to Exploration
Texas Instruments	Under the HRP Education and Outreach and Texas Instruments Education Division NASA Space Act Agreement, a virtual math camp was held and new content was developed for the Math and Science @ Work and Exploring Space Through Math projects
American Association of Retired Persons Convention; Hispanic Engineering, Science, and Technology Week; National Space Symposium; NASA Day on the USS Intrepid; NASA-on-the-Hill	Allowed for public dissemination of information on the Human Challenges of Space Exploration

The HRP organizes and participates in international collaborative meetings and coordinates research and technology workshops. The workshops are conducted to inform researchers outside of NASA about the HRP's research and to obtain information about research going on outside of NASA.

International Coordination Meetings and Research and Technology Workshops

Meeting	Meeting Description
International Space Life Sciences Working Group (ISLSWG) http://www.nasa.gov/exploration/about/islswg.html	Works to bring agencies together by identifying their mutual interests and programmatic compatibilities, enhancing communication, and encouraging a unified effort among the participating space life sciences communities around the world
Meeting of the US-Russian Joint Working Group	Discussed space biology and space medicine emphasizing ISS research and opportunities for collaboration, and education and outreach opportunities to inspire the next generation of scientists and physicians who will work in future human spaceflight endeavors
Human Research Program Investigators' Workshop http://www.dsls.usra.edu/meetings/hrp2010/	Tutorials and panel discussions to address opportunities, processes, resources, and strategies to optimize HRP research
61st International Astronautical Congress Space Life Science Symposium http://www.iafastro.com/?title=IAC2010	Shared information about space for human benefit and exploration, and promote information on HRP Education and Outreach activities
21st Annual NASA Space Radiation Investigators' Workshop http://www.dsls.usra.edu/meetings/radiation2010	Provided an opportunity for active researchers in the NASA Space Radiation Program to share the results of their work and to explore new directions of research that may benefit the NASA program

Meeting	Meeting Description
Bone Summit	The summit addressed the risk for early onset osteoporosis in long-duration astronauts and key recommendations were made on how research data can be used by space medicine
Occupant Protection Summit	Met to formulate a recommendation for an acceptable level of injury risk associated with spacecraft landing scenarios
Workload Scales, Measurement, and Management Workshop	Met to gain the most current workload scales-, measurement-, and management-related information relevant to NASA needs
EVA Biomedical Sensor Workshop	The requirement for independent methods of measuring metabolic rate was developed as a product of this workshop
Lunar Surface Systems Radiation Workshop	The workshop was held to extend the dialogue on how to meet the technical and programmatic challenges of lunar surface radiation risk mitigation through an integrated systems approach
Virtual Conference Celebrating the Apollo Program http://www.smithsonianeducation.org/educators/professional_development/conference/2009/apollo/index.html	HRPEO teamed with the Smithsonian Air and Space Museum to host a virtual conference to celebrate the Apollo Program in conjunction with the Apollo 11 lunar landing 40th Anniversary
18th International Academy of Astronautics Humans in Space Symposium http://www.dsls.usra.edu/meetings/IAA	To share information among international agencies and researchers including progress updates in the field of countermeasure research and development



Standing Review Board Site Visit at JSC

The HRP provided a status briefing to its Standing Review Board (SRB) during the SRB's site visit to the Johnson Space Center in August 2010. They were given a summary of progress and accomplishments of the HRP since its Program Implementation Review in 2008 and Interim Program Implementation Review in 2009.

The briefing also addressed issues and concerns raised during these previous reviews; an overview of the HRP Planning, Programming, Budgeting, and Execution budget submission; an HRP Program Manager's assessment of program standing; and an appraisal of the HRP position in the changing NASA human space exploration environment. The SRB provided informal feedback to the HRP indicating that the program was in good standing and recommended increased focus on data accessibility and the development of a strategy for prioritizing HRP content.

Standing Review Panels Provide Recommendations for Element Science Content

The HRP's Integrated Research Plan (IRP) was reviewed by a series of Standing Review Panels (SRP) conducted during the fall of 2009. Seventy-

five panel members drawn from university faculties, civil servants, and industry experts were divided into twelve panels. The panels reviewed the overall strengths and weaknesses of the IRP and provided recommendations for improvement. The review included a critique of identified gaps in understanding of the consequences or likelihood of HRP risks, gaps in the ability to mitigate these risks, and the tasks selected to be completed to fill those gaps.

Eleven of the panels were aligned with the HRP risk groupings: bone/muscle, immune, nutrition, cardiovascular, sensorimotor, extravehicular activity, Behavioral Health and Performance, Advanced Environmental Health & Advanced Food Technologies, Human Factors Engineering, Space Radiation, and Exploration Medical Capability. An additional panel provided a higher level of review of the risks in the Human Health and Countermeasures Element.

A total of nearly six hundred recommendations from all panels were compiled and provided to HRP management. The recommendations were addressed, vetted, and responded to by each element at a series of Science Management Panels. These preliminary responses were then formalized into a written document and provided to each SRP. The SRP's recom-

Major Program-Wide Accomplishments

mended the addition of 40 new gaps to the IRP. As a result, the IRP was revised in June 2010 and contains the HRP's comprehensive response to the SRP recommendations. These panels will convene on a yearly or biennial basis to provide continuous review of the HRP.

HRP Web-Based Documents & Information

The Human Research Program's Evidence Book is a collection of evidence-based reports, one for each risk to human health and performance listed in the HRP Program Requirements Document. The HRP has developed an IRP for these risks which identifies the approach and research activities necessary to address the needs of human space exploration. The Human Research Roadmap is the web-based tool for communicating the Integrated Research Plan. These documents are accessible on public websites:

Program Evidence Book –

http://humanresearch.jsc.nasa.gov/elements/smo/hrp_evidence_book.asp

Program Requirements Document –

http://humanresearch.jsc.nasa.gov/files/HRP-47052_PRD.pdf

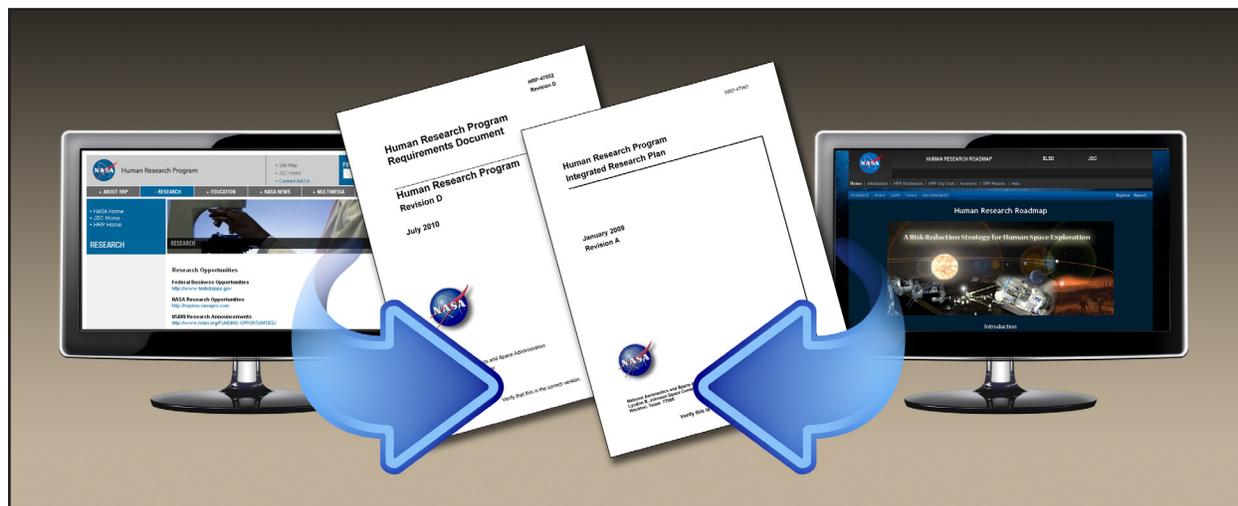
Human Research Roadmap –

<http://humanresearchroadmap.nasa.gov>

Data Accessibility Survey

Obtaining access to sensitive data from human test subjects has historically been problematic for researchers. Improving access to such data can help the research community provide a better understanding of the strategies required to mitigate spaceflight-related health risks. Without proper access to data, the analysis of risks and/or assessment of gaps can be incomplete or flawed. Furthermore, understanding of the problem may be incomplete, which could lead to the inability to reach qualified researchers and/or an increased likelihood of receiving proposals that lack focus on closing identified gaps.

Five key improvements were made to improve data accessibility. The Longitudinal Study of Astronaut Health database was updated to ensure that data was more accessible and the process for acquiring data was clearly defined and managed. Evidence reports were made available to the public. Medical Requirements Integration Documents were posted on the website and links to this information were provided in HRP NASA Research Announcements (NRA). Presentations on accessing data were provided to the HRP community. Beginning in 2009, a Data Accessibility Survey became routine at the annual HRP Investigators' Workshop.



Many HRP documents are available to the general public via NASA websites such as www.nasa.gov/exploration/humanresearch

The survey was created to take a baseline measurement of the knowledge of the investigator community about access to data. In addition, the survey captured usage and quality of the data.

In comparing 2010 survey results with those of 2009, in all but two cases, there seemed to be an increase in knowledge of how to access data. However, in both years, the survey response rate was low. Forward work includes focusing on adding a link to data accessibility information on associated websites, improving the website used to access data, and creating a team of experts to improve the 2011 survey and address shortfalls.

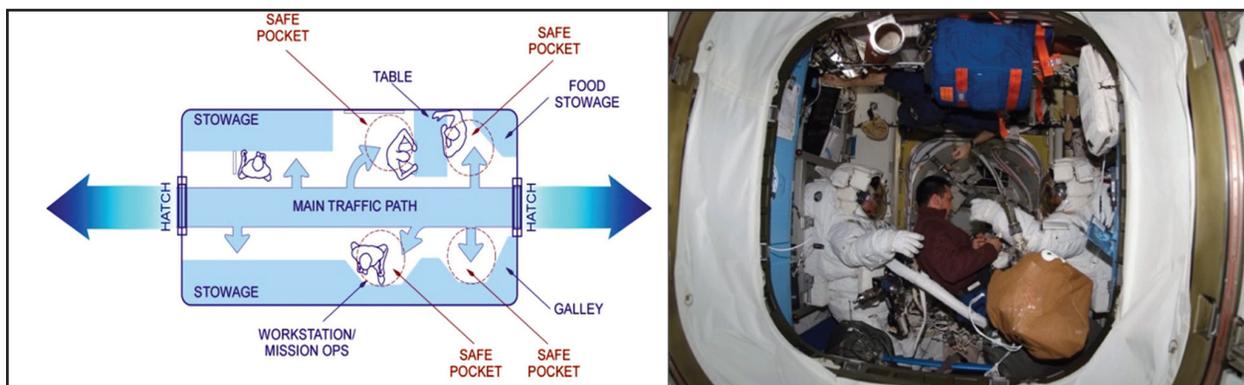
Space Flight Human-System Standard and the Human Integration Design Handbook

NASA created the Man-System Integration Standards (NASA STD-3000) in 1985 to establish human engineering standards for human spaceflight and to make the ISS more habitable and “user-friendly.” Since then, many important lessons have been learned from the Space Shuttle and International Space Station programs. Researchers within NASA and across the country have developed better ways to design displays and controls, to provide an environment for living and working, and to keep crews healthy in space. New technologies and information from twenty-five years of progress has led to the need to replace NASA-STD-3000.

In response to this need, NASA-STD-3001, Space Flight Human-System Standard Volume 2 (SFHSS V2) and the Human Integration Design Handbook (HIDH) were developed to supersede NASA-STD-3000. SFHSS V2 contains requirements, from the human and environmental factors disciplines, for performing safe, efficient, and effective human spaceflight operations. Furthermore, it applies to all future spaceflight programs and thus includes both specific and general requirements.

The HIDH is a companion document to SFHSS V2 and contains human-system integration data and lessons learned from previous human programs – a compendium of human spaceflight history and knowledge. It provides useful background information and research findings to support the development of program-level requirements and is intended to aid interpretation of SFHSS V2 requirements and to provide guidance for requirement writers and vehicle and habitat designers.

Development of these documents has required significant contribution and collaboration across NASA. SFHSS V2 was sent to the NASA Technical Standards Program for Agency review and subsequent NASA all-Center concurrence. As a result of the comments received and changes made in the initial NASA all-Center concurrence, a second NASA all-Center concurrence was initiated in October of 2010. The standard is on schedule for final baselining through the NASA Technical Standards Program



NASA SFHSSV2 standards specify clearances for traffic paths (left). Large amounts of stowage on the ISS (right) make it difficult to maintain these pathways.

in late 2010. The HIDH was made publicly available through JSC's Scientific and Technical Information Program as a special publication, NASA/SP-2010-3407 http://ston.jsc.nasa.gov/collections/TRS/_techrep/SP-2010-3407.pdf.

Human Research Program Solicitations

The 2009 NRA for “**Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions**” jointly solicited proposals for NASA and the NSBRI. Proposals were solicited by NASA in the areas of sensorimotor, muscle and bone, cardiovascular and muscular endurance, intervertebral disc damage, and advanced food technology. In addition, proposals were solicited by the nsbri in the areas of cardiovascular alterations and smart medical systems and technology. Eleven awards were announced in April 2010. Seven of the projects joined the HRP's team of principal investigators, and four joined NSBRI's team-based research program.

The 2010 NASA NRA titled “**Research and Technology Development to Support Crew Health and Performance in Space Exploration Missions**” was released in July. This NRA also jointly solicited proposals for NASA and the NSBRI. NASA topics included host-microbe interactions, crew microbiome, workload measures, habitability concept tools, psychosocial aspects of food acceptability, neuro-cognitive performance, team autonomy, behavioral health and performance ISS utilization, muscle and EVA physiology. NSBRI topics included cardiovascular alterations, human factors and performance, musculoskeletal alterations, neurobehavioral and psychosocial factors, sensorimotor adaptation, and smart medical systems and technology. Relevancy reviews were performed in September, and step-2 invitations were issued in October. Final NRA selections will be announced in April 2011.

The NRA titled “**Ground-Based Studies in Space Radiobiology**” was released in January 2010. This NRA solicited ground-based proposals for the HRP

Space Radiation Program Element (SRPE). Specific areas of emphasis included Radiation Quality and High-Energy Particles (HZE) Carcinogenic Processes, Late Central Nervous System (CNS) and Degenerative Risks from Space Radiation, Studies of Individual Radiation Sensitivity and Radiation Quality, and HZE Tumor Dose Response Models. Proposals were solicited in the area of space radiation biology to use beams of high-energy heavy ions to simulate space radiation at the NASA Space Radiation Laboratory at Brookhaven National Laboratory. A peer review was conducted to evaluate step-2 proposals. Eleven awards were announced in August.

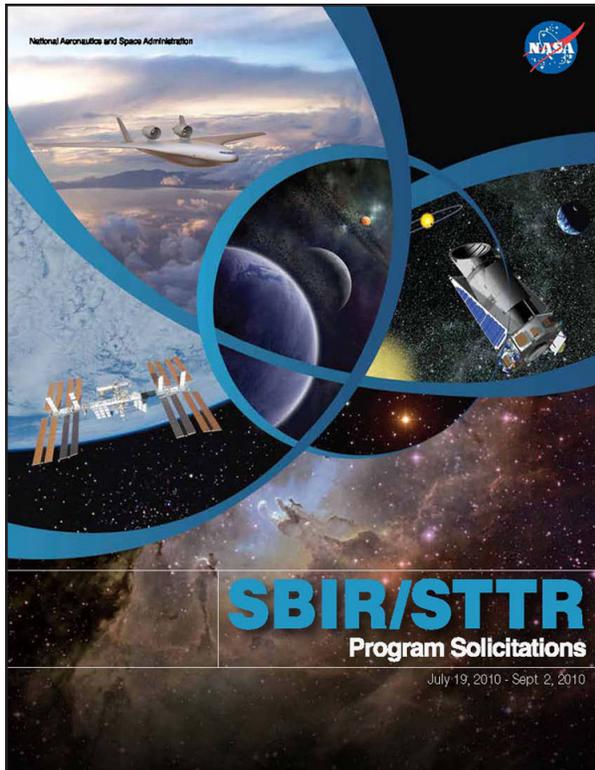
The NRA “**NASA Specialized Centers of Research (NSCORs) and Virtual NSCOR (VNSCOR) for Space Radiation Solid Cancer Risks and Biological Countermeasures,**” was released in April 2010. The central focus of the solicitation was research that will provide the basis for improved estimation and uncertainty reduction for the risk of solid cancer being caused by space radiation; additional goals were to develop new cutting-edge approaches to biological countermeasures for solid cancer risks from HZE nuclei. A peer review was conducted in September to evaluate the proposals, and awards were announced in November.

The NASA Small Business Innovation Research (SBIR) Program Management Office released the 2010 SBIR Phase 1 Solicitation in July. The six HRP topics included in the solicitation were exploration crew health capabilities, exploration medical capability, behavioral health, human factors and food systems, radiation, and in-flight biological sample preservation and analysis. Proposals were reviewed, and awards were announced in November. In addition, 2009 SBIR Phase 2 awards were announced in October.

NASA Engages the Public with Open Innovation Challenges

The HRP sponsored a number of challenges inviting the general public to submit solutions to specific

Major Program-Wide Accomplishments



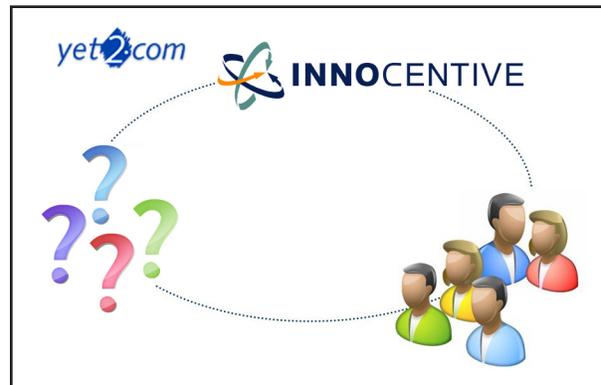
The goal of the NASA Small Business Innovation Research Solicitation is to engage small businesses to develop solutions in response to specific needs.

technology needs. The purpose of this effort was to test the viability of an external OISP's ability to aid in solving NASA's specific knowledge and/or technology gaps. Two Open Innovation Service Providers (OISP) were used to advertise HRP's needs and then to identify potential solution providers. The companies chosen were InnoCentive and Yet2.com.

The OISP choices were based on multiple factors, including network size and knowledge area span, established process, experience base and cost. Both companies met the desired criteria, however, they approach open innovation using two distinctly different methods. Thus, both companies were chosen in an effort to define which method of Open Innovation best serves NASA's needs based on the initial set of test challenges and gaps.

Some of the challenges were "Design of a Mechanism for a Compact Aerobic and Resistive Exercise

Device", "Improved Barrier Layers for Keeping Food Fresh in Space", "Simple Microgravity Laundry System", and "How to Augment the Exercise Experience with Audio-Visual Inputs". To date, all of the HRP challenges have returned ideas that were eligible to be awarded prizes.



HRP has employed firms such as Yet2.com and InnoCentive to bring 'seekers' and 'solvers' together to find creative solutions to specific challenges.



NASA Extreme Environment Mission Operations 14 Studies

The 14th NASA Extreme Environment Mission Operations (NEEMO) mission was conducted in May of 2010 and included multiple HRP Element and Project studies. NEEMO is a high-fidelity space analog environment similar to spaceflight and is located at the Aquarius Undersea Laboratory located on the ocean floor about 3.5 miles off the coast of Key Largo, Florida.

The NEEMO 14 crew consisted of four NASA “aquanauts” – two of which were astronauts and two were members of the HHC EVA Physiology, Systems and Performance (EPSP) team. Together with two professional aquanauts from the University of North Carolina-Wilmington, which manages the habitat, the crew performed all data collection objectives of the HRP investigations.

This was the most complicated NEEMO mission to-date based on the mission timeline, pace, and number of planned activities. HRP personnel supported the mission from the NASA Mobile Mission Control Center that provided real-time monitoring of video and audio feeds from inside and outside the habitat, including live camera feeds from each of the EVA helmets during excursions outside Aquarius.

The EPSP Project collected data across each extra vehicular activity (EVA) day, and captured crew comments during each of twelve EPSP-specific EVAs. The crew of “aquanauts” conducted a series of EVAs, simulating activities that astronauts would likely perform during missions in space. Using near-scale mockup vehicles, EVA teams conducted off-loading, retrieval, and survival missions, including the transfer of a simulated incapacitated astronaut from the ocean floor to the deck of the Lander.



From inside the Aquarius habitat, a NEEMO Aquanaut directs fellow aquanauts performing an EVA on the ocean floor.

Major Technical Accomplishments

The Non-exercise Physiological Countermeasures (NxPCM) Project sponsored two research investigations during the mission: the immunology and nutrition studies required collection of blood, urine, saliva, and exhaled air samples from crew members before, during, and after the mission for subsequent biological analysis. New for this mission, an operations-compatible method was developed to handle samples collected during undersea operations and preserve them for transport to European Space Agency (ESA) collaborators.

This setting provided a perfect environment for the BHP study “Assessing Team Performance in Autonomous Environments.” Results provided insight into the importance of team training for critical and novel tasks and demonstrated how autonomy influences team performance and other important team factors. The cognitive performance study “Cognitive Performance and Stress in a Simulated Space Environment” further evaluated what the best measures and tools are to use for assessing negative impacts in cognitive function due to fatigue.

The aquanauts’ schedule closely mirrors that of a crew in-orbit. This similarity provided an analog environment for the BHP study “A Scheduling and Planning Tool in NEEMO 14 – A Simulated Space Environment” to be conducted. NEEMO provided

a platform to test the Scheduling and Planning Interface for Exploration (SPIFe), a software tool designed to plan activities in a mission operational setting and will assist with scheduling, planning, and training of the astronauts during long-duration spaceflight missions. The SPIFe feasibility study received valuable input regarding usability from both the aquanauts and the ground support team during NEEMO 14.

Human Research Facility Muscle Atrophy Research and Exercise System

The Muscle Atrophy Research Exercise System (MARES), a joint project between NASA’s Human Research Program and the ESA, launched on space shuttle mission STS-131 in April 2010 and was delivered to the ISS. Scientists and engineers working on the project overcame numerous technical challenges throughout its fourteen years of development. After it was delivered, the MARES was assembled and configured for initial checkout during ISS Increment 24. Various technical issues that arose during these operations will need to be resolved in FY2011, before the system is commissioned for future research.

Once it is fully functional, the MARES will be used to carry out research on musculoskeletal, biome-



NEEMO 14 aquanauts performed 22 EVAs on full-scale mockups to evaluate suit weight and center of gravity on their ability to effectively perform EVA tasks.



A NASA astronaut works with Muscle Atrophy Resistive Exercise System hardware during installation in the Columbus laboratory of the ISS.

chanical, neuromuscular, and neurological physiology, to study the effect of microgravity on humans and to evaluate countermeasures to the physiological effects induced by the space environment. The MARES can also be used to evaluate exercise test protocols.

Direct Crew Return Implemented with 21Soyuz

The crew of the Russian space mission 21Soyuz returned from the ISS after completing their 163-day mission. After the Soyuz spacecraft landed, the NASA and Japanese Space Agency crewmembers participated in the first instance of Direct Crew Return and were transported directly from Kazakhstan to the U.S. Before Direct Crew Return was implemented, the standard process delayed crew return to the U.S. for several days complicating post-flight data collection.

Utilizing Direct Crew Return, crewmembers arrived in Houston within 24 hours of their descent from space. Returning with the crew were blood and saliva samples collected during flight in support of the Integrated Immune investigation.

Direct Crew Return allowed postflight studies to begin on the return trip, gave the crew an opportunity to rest after their stressful return to Earth, and enabled a full schedule of postflight medical and



The Soyuz spacecraft touches down in Kazakhstan returning members of the Expedition 22 and 23 crews after serving six months onboard the ISS.

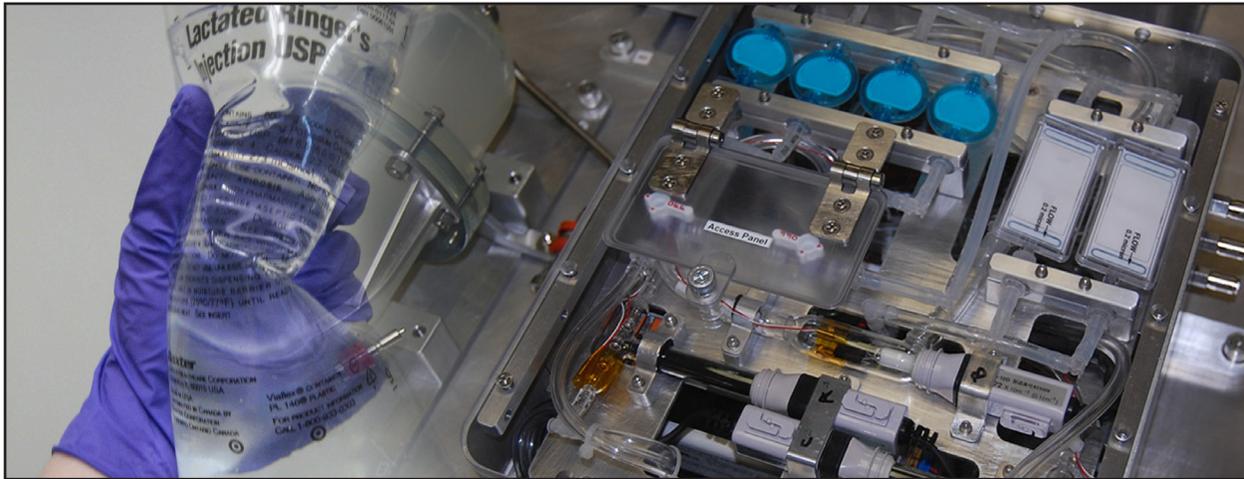
science testing to be conducted. It also significantly reduced the need for science investigators to travel and to outfit testing hardware in Russia to perform postflight research. Direct Crew Return was also successfully used for the return of the 22Soyuz crew and will be used for subsequent landings.

IntraVenous Fluid GENERation (IVGEN) Samples Analysis

The IntraVenous Fluid GENERation (IVGEN) hardware was developed by Exploration Medical Capability (ExMC) personnel to close the research gap “Lack of In Situ Intravenous (IV) Fluid Generation Capability.” The IVGEN project was developed to design and test a system capable of producing United States Pharmacopeia (USP)-grade IV fluid using available in-orbit resources. About twelve liters of IV fluid are required during ISS missions, and potentially more during exploration missions beyond Earth orbit. Because IV fluid has a finite shelf life and the vehicle restrictions on mass and volume, resources could be saved by flying a purification system capable of generating IV fluid when it is needed.

Studies were conducted at the Glenn Research Center (GRC) to identify the appropriate purifying and mixing technologies that could produce USP-grade IV fluid. In conjunction with purifying and mixing, the team identified portions of the process that could be negatively affected by microgravity, and designed hardware that could function independent of gravity. The hardware utilized a cartridge containing deionizing (DI) resin and air-removal and sterilization filters to purify water supplied by the ISS Water Processing Assembly. ZIN Tech., Inc. supported the design and fabrication of the hardware and in-flight testing. The hardware was shipped to the Kennedy Space Center for integration into the Multi-Purpose Logistics Module and launched to the ISS in April 2010.

During in-flight testing, ISS astronauts successfully produced two 1.5-liter bags of 0.9 percent normal saline solution. The IVGEN team then continued hardware operations to determine how much water



could be processed before exhausting the filters. An additional six liters were produced by IVGEN, without exhausting the purifying capacity of the DI resin cartridge. In fact, the DI resin cartridge operated with 99 percent efficiency at the end of the last run. The two bags of normal saline solution were returned on STS-132 and subsequently transported to a USP-certified laboratory to test the contents.

Results indicated that IVGEN passed all components of the USP requirements, except for the normal saline concentration, which was slightly outside of the expected range. However, it was determined that the saline concentration produced was well within limits tolerated by the body and the fluid would have been suitable for use.

Mission Medical Information System Database to Support Research and Medical Operations

The Mission Medical Information System (MMIS) is a ground-based data management system that allows laboratories to submit their reports and gives flight surgeons and epidemiologists access medical data. The Exploration Medical Capability (ExMC) Element funded an expansion of the MMIS that allows researchers to have access to crew health data.

Medical operations require the collection of health and physiological data from crewmembers during ISS missions. JSC laboratories receive the data from

the ISS, perform analyses, and generate reports. The end customers of the information are the crew flight surgeons and epidemiologists. Processes have been put in place to approve and publish the reports and to manage the original data that was downlinked from the ISS. The goal of the MMIS project was to electronically facilitate this process securely and rapidly while maintaining availability of the reports and data to the end user.

The MMIS team worked closely with the JSC clinical laboratories to simplify the input of data collected. Data submission agreements were generated to control the data that would be submitted into the MMIS. This data is stored within a database so that it can be queried by epidemiologists should it be needed for a study in the future. It is through this mechanism that external researchers can access clinical data for long-term studies of the same individuals.

Completion of the MMIS is a significant milestone in providing electronic processes for management of data. Input of the data is simple and does not interfere with the data collection and analysis processes of laboratories. End users have access to all crew health and performance data in a common ubiquitous user interface that eliminates the need to learn new software. Overall, MMIS can continue to support and grow with the expansion of crew health and performance data and human space flight.

New Studies to Optimize On-Orbit Exercise Protocols

Two new Exercise Countermeasure Project (ECP) studies selected for flight in 2010 will provide data to make current ISS exercise protocols more effective. The Treadmill Kinematics Study will be the first investigation to collect biomechanical data from ISS crewmembers during exercise with the Combined Operational Load-Bearing External Resistance Treadmill (COLBERT). ISS treadmill exercise requires use of a subject loading system to tether the crewmember to the treadmill and create a load equal to or greater than what the body weight is in Earth's gravity. This study will evaluate how exercise may be affected by varying the exercise speed and the load produced by the subject loading system. Find-



A NASA astronaut equipped with a bungee harness, exercises on the Combined Operational Load Bearing External Resistance Treadmill in the ISS.

ings will be used to develop more effective, targeted exercise prescriptions to maintain musculoskeletal health. The first crew participant for the Treadmill Kinematics Study will be in 2011.

The second new exercise optimization study selected for flight in 2010, the “Study on Periodized Resistance and Interval Training (SPRINT),” will also begin on-orbit operations during in 2011. The SPRINT study will, for the first time on the ISS, incorporate resistance exercise and aerobic exercise in high-intensity, short-duration “interval” protocols in a systematic manner over the entire mission duration. The study includes a wide battery of fitness-related measurements that will allow a detailed evaluation of the interval exercise program’s effectiveness for protection of cardiovascular, skeletal muscle, and bone health. The SPRINT protocol also includes in-flight fitness assessments to allow the exercise prescription to be modified in-orbit as necessary. Also, for the first time on the ISS, muscle ultrasound will be used during flight to evaluate muscle atrophy.

Vitamin D Supplementation: Evaluation of Dosing Regimen Study

The second vitamin D supplementation study was conducted at McMurdo Station, Antarctica, in 2009. JSC personnel traveled to Antarctica to train McMurdo personnel and to recruit study subjects. Participants collected blood and saliva samples, and tracked dietary intake for each of three data collection sessions: beginning, middle, and end of winter. All subjects were provided with vitamin D supplements, either 2000 International Units (IU) per day or 10,000 IU taken once per week. Samples were received at JSC in November of 2009. They were analyzed for vitamin D and markers of calcium and bone metabolism, as well as for markers of virus reactivation. Examining the amount of reactivation of a latent virus, which the immune system normally prevents from being reactivated, enabled researchers to evaluate the relationship between vitamin D and immune system function, both of which are known to be compromised in subjects wintering over in



McMurdo station in Antarctica, the location for the polar studies is an ideal analog for isolation studies.

Antarctica. In FY2010, the data and statistical analyses are near completion, and the final report and publication are in work. The next steps will depend on the findings from this study and discussions among the team of investigators.

Assessment of Shuttle Astronauts' Sleep Behaviors and Sleep Quality on Earth

The Behavioral Health and Performance Element (BHP), in conjunction with the Space Medicine Division (SD) of JSC's Space Life Sciences Directorate, completed the largest systematic, subjective assessment to date of shuttle astronauts' sleep behaviors and sleep quality on Earth. From July 2009 to March 2010, a total of 66 astronauts completed a secure online survey regarding specific sleep strategies, crew policies, and mitigation effectiveness. In addition to the survey, each participant met individually with trained representatives for a structured follow-up interview.

Results indicate that there is large degree of individual variability in the overall quality of sleep that astronauts reported in flight. More than half of the crewmembers indicated difficulty with sleep in-orbit. There was a significant relationship between difficulty falling asleep on Earth and experiencing sleep disruptions in flight. More than half of the crewmembers, rated "wind-down time" as an important part of sleep onset. Methods of winding down



Providing a quality sleep environment during spaceflight requires overcoming several challenges. The STS-112 crewmembers sleep on the middeck of the space shuttle Atlantis.

included spending time with crewmates, listening to music, reading, and watching movies. Other countermeasures such as medications, and flight rules and requirements were discussed.

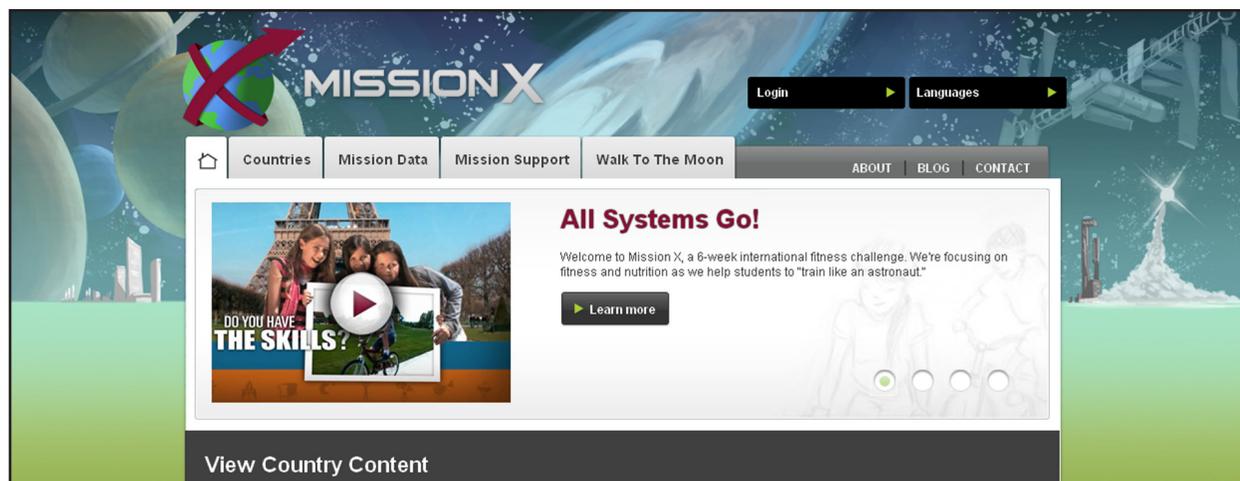
Findings from this investigation will inform countermeasure strategies for astronauts, medical operations personnel, and habitat designers for future exploration missions, as well as upcoming shuttle and ISS missions. Another phase of this study is planned with ISS long-duration crewmembers.

Russian IBMP 105-Day and Mars500 Isolation Chamber Studies Report

BHP Investigators with the NSBRI participated in a 105-day isolation study to gather data on crew health and performance during long-duration space missions. An international crew, consisting of four Russian Space Agency and two ESA participants, stayed for 105 days inside the Institute for Biomedical Problems' (IBMP) isolation facility in Moscow. NSBRI's three research projects evaluated crewmember morale under various autonomy conditions, the effectiveness of lighting countermeasures, and the impact of stress and fatigue on performance. Findings from the studies revealed that crewmember mood was rated more positively under high-autonomy conditions than under low-autonomy conditions; crew responses may have been affected by cultural factors. In assessing fatigue and performance, ratings of stress and unhappiness using the Visual Analog Scales (VAS) did not change during the 105-day mission. In contrast, VAS mental fatigue declined and alertness improved significantly across time in the mission. An objective measure of fatigue, the optimized three-minute Psychomotor Vigilance Task, did not show increasing errors across time in the mission. Lessons learned from the investigations were used to conduct a U.S. investigation in the IBMP 520-day isolation study, Mars500.



The Russian IBMP Chamber where a crew of six lived for the 105-day isolation study where investigators studied mood, morale, and the impact of stress and fatigue.



Overview

The Human Research Program Education and Outreach (HRPEO) Project is committed to using NASA's expertise in space research and exploration to educate the nation in science, technology, engineering, and mathematics (STEM). Project activities and materials target educational communities, the general public, policymakers, and the media using formal and informal venues. The HRPEO Project has made significant progress in strengthening their K-12 programs and outreach efforts during the past year. Their primary-grade programs include the 21st Century Explorer and Fit Explorer initiatives. Secondary programs include Math and Science @ Work, and Exploring Space through Math. The Mission X: Train Like an Astronaut project, formerly known as the Space Explorer International: Fitness Challenge 2010, is now approaching the close of its development phase and preparing for its first international fitness challenge in January 2011. To learn more about HRPEO please visit:

www.nasa.gov/exploration/humanresearch/education

Mission X: Train Like an Astronaut

NASA's Fit Explorer project, a precursor to "Mission X: Train Like an Astronaut", is a scientific and physi-

cal approach to human health and fitness on Earth and in space. Students complete physical mission activities and science investigations modeled after the real-life requirements of humans in space. As Fit Explorer expanded its development, NASA began working with its partners from the International Space Life Sciences Working Group to develop the multi-national pilot challenge, Mission X: Train Like an Astronaut. Mission X is designed as an internationally focused, joint education and outreach challenge that integrates fitness, nutritional, and educational content from multiple space agencies and institutions.

This project's unique approach to human health on Earth and in space addresses health and fitness education, challenges students to be more physically active, increases awareness of the importance of lifelong health and fitness, teaches students how fitness plays an important role in human performance in space exploration, and inspires and motivates students to pursue careers in STEM fields.

Other 2010 Mission X products and highlights include extensive international coordination, the creation of an exciting thirty-second public service announcement publicizing the challenge in six lan-

guages, the preparation and translation of twenty-six challenge content pieces in six languages, the development of the Mission X Challenge website, and the planning and execution of teacher training.

For details visit: www.trainlikeanastronaut.org

Education Technology Partnership with Texas Instruments

Through the recently signed Space Act Agreement between HRPEO and Texas Instruments (TI) Education Division, twelve outstanding teachers from across the U.S. joined the HRPEO team at JSC to develop new curricula for the high-school projects, Math and Science @ Work, and Exploring Space Through Math. The group included educators and master instructors from the Texas Instruments Teachers Teaching with Technology cadre. Participants were treated to a tour of JSC facilities and given an overview of the work performed by human spaceflight scientists and engineers. The visit provided the data and information the teachers needed to create real-world problems and activities for the classroom. Drafts of more than 30 new classroom problems for high-school STEM classrooms, including advanced placement (AP) courses, were developed. The draft curricula will be developed into classroom-ready materials over the course of the next two years.

During July 2010, under the Space Act Agreement, a Virtual Math Camp was conducted for students



Math and science educators visit the Johnson Space Center to prepare a curriculum for the Virtual Math Camp.



ETHOS Flight Controller conducts a webinar for the HRPEO and Texas Instruments Math Camp, Mission: Math and Science Virtual Camp.

in Algebra 1 through AP Calculus and AP Physics. The content focused on HRPEO's high-school supplemental material and the TI-Nspire™ handheld computer. During the camp week, two webinars were conducted. The first provided an overview of shuttle ascent activities and the console position of flight dynamics officer. The second was led by NASA personnel who discussed the ISS and training specific to their console position, Environmental and Thermal Operating Systems (ETHOS).

Discussion boards and forums were implemented for each activity, and NASA personnel monitored and participated in the discussions with the camp students on the NASA topic. A TI facilitator moderated the board and participated in the discussions to address the math topics and any issues that students had with the TI-Nspire. Thirty students participated in the various camp activities.

Girl Scouts of the United States of America

NASA's 21st Century Explorer is a national standards-based program that uses web-based and multimedia technology to enhance STEM and introduce NASA space exploration concepts. In FY2010, HRPEO began the NASA-Girl Scouts USA research study to provide a group of adults and children who to help evaluate the effectiveness of the 21st Century Explorer educational materials to inspire and educate girls in STEM.

The first study in July 2010 were two groups consisted of leaders and Girl Scouts ages 8 to 11 from the Iowa Girl Scout Council. The leaders were trained and a total of forty-three girls participated in the three summer camps. A mixed-methods approach was used to evaluate changes in attitudes relating to NASA and STEM. Additional surveys were administered to collect information on the effectiveness of the training for Girl Scout leaders.



The Arizona Girl Scout Council was recently selected as the site for the second study. The intent is to complete the second study in the summer of 2011, and complete the research study results by the end of the year.

NASA Space Radiation Summer School

The HRP Space Radiation Element, in support of developing the next generation of radiobiology researchers interested in space, selected seventeen students to attend the 7th annual NASA Space Radiation Summer School held at the Brookhaven National Laboratory. Participants included domestic and foreign graduate students as well as faculty in biology and physics. The extensive course content includes lectures and labs in radiobiology, nuclear physics, health physics, radiation-induced health effects, risk modeling and radiation protection.

Space Life Sciences Summer Institute

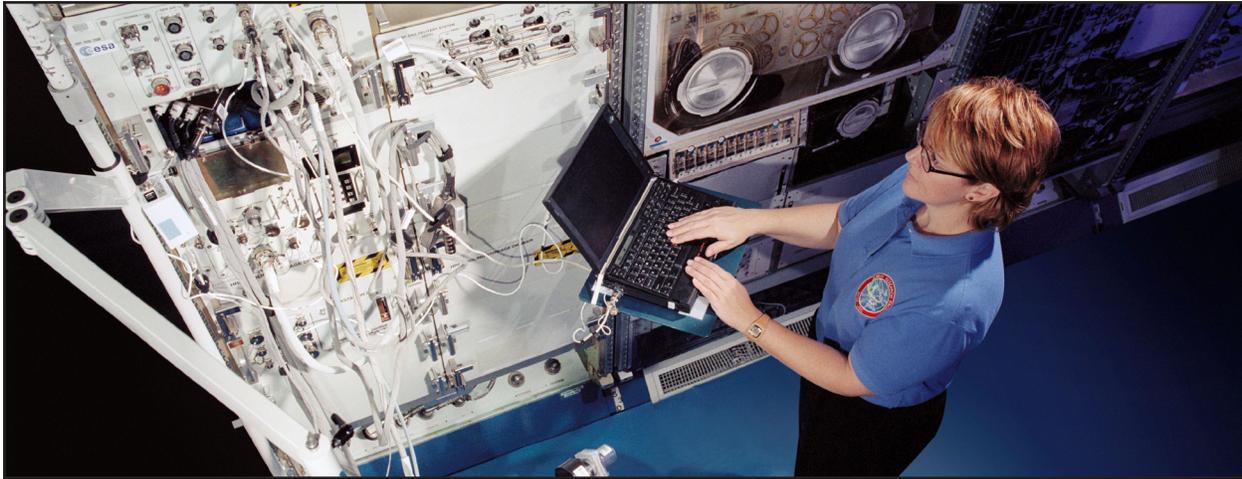
The 6th Annual Space Life Sciences Summer Institute (SLSSI) was held for student interns during 9-weeks beginning in June 2010. Interns were selected from across the U.S. and Canada included undergraduate, graduate and medical students in various majors and disciplines. They are assigned NASA scientists, physicians, and engineers as mentors to work with them on individual projects participating in ongoing research activities.



The 2010 summer interns staged a re-enactment of an original photo from MCC of the Apollo 13 splashdown.

To augment their internship, students participate in the SLSSI. The purpose of the Institute is to offer a unique learning environment that focuses on the current biomedical issues associated with human spaceflight in support of space exploration. It provides an introduction of the paradigms, problems, and technologies of modern spaceflight cast within the framework of life sciences. A series of interactive lectures are provided to familiarize students to the various aspects of space physiology and environments.

In addition to the lecture series, behind-the-scenes tours are offered that include the Neutral Buoyancy Laboratory (NBL), Mission Control Center (MCC), space vehicle training mockups, and a hands-on demonstration of the Space Shuttle Advanced Crew Escape Suit (ACES). The Institute faculty include NASA scientists, flight surgeons, flight controllers, engineers, managers, and astronauts. While the Institute is managed and operated at JSC, student interns from Glenn and Ames Research Centers also participated through webcast distance learning capabilities.



Overview

The International Space Station Medical Project (ISSMP) provides the bridge between flight research and medical operations by planning, integrating, and implementing human research requiring access to the ISS, Shuttle, Soyuz, Progress, or other spaceflight vehicles. Their support includes pre- and post-flight activities on the ground and science operations in flight, including activities requiring access to in-orbit facilities such as the Human Research Facility.

During FY2010, ISSMP personnel coordinated and optimized the research supporting four shuttle missions and ISS Increments 21-25. Their activities included the launch and return of supplies and samples on each shuttle flight, launch of supplies on five Russian Soyuz and Progress flights, and return of samples on three return Soyuz flights.

Four investigations completed all in-flight operations and nine studies continued in-flight operations. Also, three new investigations began initial flight operations, two new investigations began development of flight products to support future missions, and three investigations awaited a future “select-for-flight” decision after feasibility assessments were completed.

In addition to supporting HRP-sponsored research, the ISSMP provides overall coordination of pre- and postflight testing for ISS and shuttle crewmembers participating in human life sciences research sponsored by other NASA Programs and International Partner agencies. ISSMP also provides support to many of these studies through use of the Human Research Facility equipment on board the ISS.

The ISSMP works with the Space Medicine Division of JSC’s Space Life Sciences Directorate, other Program elements, and International Partners to return the data needed to address key human risk areas. The ISSMP coordinates with the Space Station Payloads Office to streamline the processes for station use, to increase the research output, and to maximize the amount of data that can be returned to guide future research to meet the objectives of the risk reduction program. To learn more about the ISSMP, visit: www.nasa.gov/exploration/humanresearch/elements/_info_element-issmp.html.

The following table provides a list of ISSMP active flight experiments, the number of human subjects they require, progress made, and status to date.



Current International Space Station Medical Project Flight Investigations

Investigation Title	Ops Title	Subjects		Status
		Required	Participation Through Increment 25	
Investigations Continuing Flight Operations in Fiscal Year 2010				
Nutritional Status Assessment	Nutrition	24	19	Subjects participating during Inc 23-24, flight samples returned from Inc 21-22, analysis in progress
Sleep-Wake Actigraphy and Light Exposure During Spaceflight	Sleep	All Shuttle 20 ISS	74 Shuttle 20 ISS	Recruited ISS subjects for Inc 24, in the process of transitioning to medical operations
Validation of Procedures for Monitoring Crewmember Immune Function	Integrated Immune	17 Shuttle 17 ISS	18 Shuttle 12 ISS	Recruited ISS subjects for Inc 26-28, Shuttle phase of study completed
Bisphosphonates as a Countermeasure to Space Flight Induced Bone Loss Preflight Zoledronate Infusion as an Effective Countermeasure for Spaceflight-Induced Bone Loss and Renal Stone Formation	Bisphosphonates	10 (5 Alendronate and 5 Zoledronic Acid)	4 (Alendronate)	Four additional crewmembers (Alendronate) are participating in this investigation during Inc 25-28
NASA Biological Specimen Repository	Repository	All	17	Subject participation Inc 23-24, flight samples returned through Inc 22, recruitment ongoing
Spinal Elongation and its Effects on Seated Height in a Microgravity Environment	Spinal Elongation	23	16 Shuttle 7 ISS	Completed flight operations with 9 shuttle and 6 ISS subjects during 2010.
Cardiac Atrophy and Diastolic Dysfunction During and After Long Duration Spaceflight: Functional Consequences for Orthostatic Intolerance, Exercise Capacity, and Risk of Cardiac Arrhythmias	Integrated Cardiovascular	12	4	In-flight operations continued throughout ISS missions in 2010. Five additional subjects have agreed to participate in future ISS missions
Maximal Oxygen Uptake During Long Duration International Space Station Missions	VO2max	12	7	After a delayed start, flight operations continued in 2010 with activities over multiple ISS missions

Investigation Title	Ops Title	Subjects		Status
		Required	Participation Through Increment 25	
Physiological Factors Contributing to Changes in Post-Flight Functional Performance	FTT	13 Shuttle 13 ISS	5 Shuttle 2 ISS	Pre- and postflight investigations completed, first long duration ISS subjects during 2010, testing continues for Shuttle and ISS
Investigations with Initial Flight Operations in Fiscal Year 2010				
Dietary Intake Can Predict and Protect Against Changes in Bone Metabolism During Spaceflight and Recovery	Pro K	16	4	Expanded version of Nutrition investigation began flight operations during ISS Inc 22 mission
Psychomotor Vigilance Test on ISS	Reaction Self Test	24	6	Investigation began operations during Inc 21 and continued during Inc 22-24. Additional subjects recruited for future ISS missions
Evaluation of Commercial Compression Garments to Prevent Post-Spaceflight Orthostatic Intolerance	ACG	8 Shuttle	2	Began testing in 2010 with Shuttle subjects, recruitment will continue until Shuttle retirement
Investigations Completing In-Flight Operations in Fiscal Year 2010				
Intravenous Fluid Generation for Exploration Missions	IVGen	N/A	1	Successfully tested during Inc 23. Hardware launched on STS-131 and samples returned on STS-132
A Comprehensive Characterization of Microorganisms and Allergens in Spacecraft Environment	SWAB	8 sessions	8 sessions	Final water collections were successfully completed and returned in early 2010
Cardiovascular and Cerebrovascular Control on Return from ISS	CCISS	6	7	Final ISS subject completed all data collection in FY2010
CSM harness SDTO: A New Harness For Use with Exercise Countermeasures - Validation of Improved Comfort and Loading with the Center for Space Medicine (CSM) Harness	Harness	6	6	Operations are scheduled for completion during Inc 25

Investigation Title	Ops Title	Required	Subjects	
			Participation Through Increment 25	Status
Investigations Initiating Flight Development Activities in Fiscal Year 2010				
An Integrated Resistance and Aerobic Training Study for the Validation of an Exercise Countermeasures Regimens Aboard the International Space Station	Sprint	40	0	Selected for flight in late 2009, flight operations scheduled to begin with Inc 27-28 crewmembers
Biomechanical Analysis of Treadmill Exercise on the International Space Station	Treadmill Kinematics	6	0	Selected for flight in FY2010, scheduled for flight operations starting with Inc 27-28
Investigations Awaiting Select for Flight Decision				
Assessment of Operator Proficiency following Long-Duration Spaceflight	Manual Control	8	0	Select for flight, decision expected in FY2011
Risk of Intervertebral Disc Damage After Prolonged Spaceflight	IVD	12	0	Select for flight, decision expected in FY2011
Temperature Regulatory and Cardiovascular Responses to Exercise during Long-Duration Space Flight	Thermo-regulation	10	0	Select for flight, decision expected in FY2011



Glenn harness back view showing load sensors and instrumentation.

Treadmill Harness Station Development Test Objective

The weight-bearing exercise afforded by treadmill running on the ISS is thought to be crucial for effective gravitational loading of the musculoskeletal system and thus for bone health in space. The current ISS treadmill harness has caused discomfort in crewmembers, including chafing, bruising, and scarring at pressure points on the shoulders and hips, and may be a major contributor to sub-optimal loading on the treadmill.

In 2010, a treadmill harness Station Development Test Objective (SDTO), sponsored by the Exercise Countermeasures Project, collected on-orbit comfort and load data in a side-by-side comparison of the current treadmill harness and a prototype harness designed for improved comfort and loading. Operations began during Increment 20/21 and continued through Increment 25. The final report for this evaluation will be available in 2011. Improved harness designs are expected to allow greater loading during exercise, potentially leading to greater health



An astronaut runs on the TVIS treadmill during testing for the Harness Station Development Test Objective.

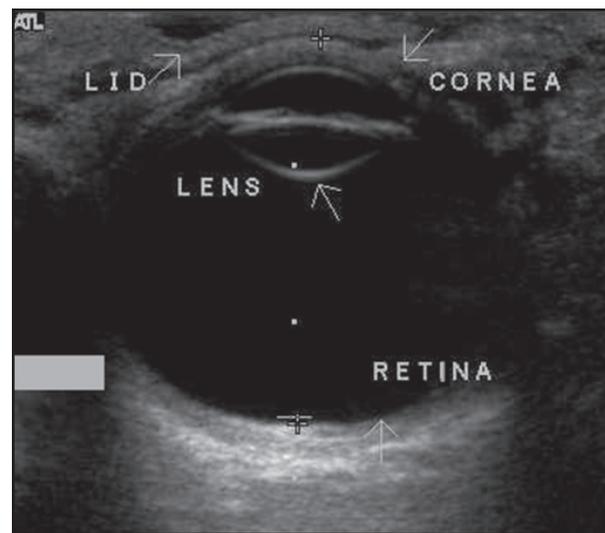
benefits from treadmill exercise, and should mitigate crew discomfort during exercise.

First In-flight Ocular Scans Using the On-board Ultrasound

Recent evidence of ocular changes in several crewmembers has identified a need to accurately and noninvasively assess the potential impact of these changes on the health of crewmembers. In collaboration with the Space Medicine Division of JSC's Space Life Sciences Directorate, the ISSMP supported the first on-orbit use of the ISSMP ultrasound instrument to monitor potential changes in the vision of crewmembers. Understanding the effects of long-duration spaceflight on human physiology not only protects the health of the crew but also enhances NASA's preparation for exploration missions.

Alternative Compression Garments

The study titled "Evaluation of Commercial Compression Garments to Prevent Post-Spaceflight Orthostatic Intolerance" began operations in 2010 with shuttle crewmembers. The purpose of this pre- and post-flight study was to investigate a method to protect returning space crews from orthostatic intolerance. Astronauts who exhibit orthostatic intoler-



This year saw the first use of ultrasound technology to assess ocular health and potential changes in crewmembers' vision.

ance are unable to maintain a normal systolic blood pressure and have elevated heart rates when standing. After being weightless, many astronauts feel faint or do faint when they stand up. This condition could be especially hazardous for crewmembers if they had to quickly get out of the landing craft in an emergency. Preliminary evidence from this study suggests the use of compression garments can significantly improve orthostatic tolerance, provide superior fit and comfort for astronauts, and the garments are easier to put on than the current anti-G suit.

Cardiovascular and Cerebrovascular Control on Return from ISS

The Cardiovascular and Cerebrovascular Control (CCISS) investigation represented a collaborative effort between NASA and the Canadian Space Agency. Operations began during Expedition 15 and were completed with their seventh subject after the Expedition 19/20 mission. Investigators studied the effects of long-duration space flight on the functioning of the cardiovascular system, specifically the heart and the blood vessels that supply the brain. The ability to maintain blood pressure and brain blood flow immediately after return to Earth from prolonged spaceflight is one of the most critical factors for crew health and safety.

The study focused on the connection between the relatively relaxed state of the heart during long periods in microgravity and the ability of the cardiovascular system to properly pump fluids after return to gravity. During two in-flight sessions, crewmembers wore a heart and activity monitor and a device to continually measure blood pressure. The heart monitor recorded the electrical activity of the heart, and the activity monitor collected data on the amount of crewmember movement during a 24-hour period. Results from the in-flight operations were compared to pre- and post-flight measurements.

Shared Medical Storage: The ISSMP Consumables Pantry

Due to the planned retirement of the shuttle and the increase to a 6-person ISS crew, HRP investigations face greater constraints on the amount of research equipment and supplies able to be delivered. To minimize the impact of these constraints and to ensure that research activities can continue, the ISSMP Consumables Pantry system was developed.

The pantry stores consumables used by more than one investigation, including blood vials, biocide wipes, syringes, and gauze. With this system, multiple research activities can be supported through a common storage system in a single location. Two consumable kits are color-coded for organization of the contents, and while they are performing an experiment crewmembers are told where to locate items. Use of this system has significantly decreased up-mass requirements of individual science investigations and has increased research operations.



The ISS consumables pantry stores supplies used by more than one investigation thereby decreasing mass requirements.



Overview

The goal of the Space Radiation Element is to ensure that crewmembers can safely live and work in the space radiation environment without exceeding acceptable radiation health risks. Space radiation differs from radiation encountered on Earth.

The main sources of space radiation are galactic cosmic rays (GCRs), which consist of protons and electrons trapped in Earth's magnetic field and solar particle events. GCRs permeate interplanetary space and include particles with high ionizing energy. At the cellular and tissue levels, these heavy ions cause damage that is largely different from the damage caused by terrestrial radiation such as x-rays or gamma-rays because of their significantly higher ionizing power and associated uncertainties in quantifying biological response. Shielding against GCRs is much more difficult than shielding against terrestrial radiation because a greater mass of shielding material is required and GCRs can penetrate shielding material.

Health risks from space radiation may include an increased incidence of cancer; acute radiation sickness; degenerative tissue damage; diseases such as heart disease, cataracts, and radiation sickness; and early and late central nervous system (CNS) damage. Cancer risks pose the largest challenge for explora-

tion. The uncertainties in cancer risk projection have large impacts on exploration mission designs, limiting NASA's ability to adjust mitigation measures such as shielding and biological countermeasures. For the CNS and degenerative risks, there are uncertainties in the dose thresholds and latency. Research is needed to optimize radiation protection practices in shielding and operational procedures to prevent acute radiation sickness.

These risks have clinically relevant implications for the lifetime of the crewmembers. For this reason, space radiation studies rely on experts in biomedicine, genetics, computational chemistry, and radiation physics to provide the following:

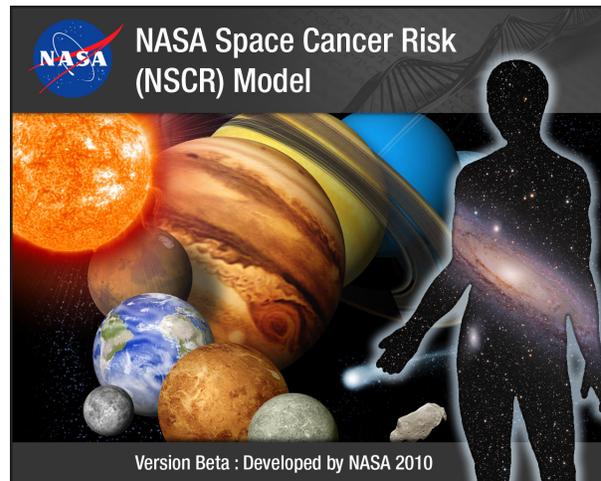
- Recommendations for acceptable space radiation permissible exposure limits (PEL) for exploration missions
- Radiobiological research on the mechanisms of health risks from space radiation and the acquisition of radiobiology data for the different types of space radiation at doses and dose rates of interest to NASA

- Development of biophysical risk projection models and computational tools to assess and project crewmembers' risk of cancer, CNS, degenerative tissue damage, and acute radiation syndromes from space radiation
- Computational tools and models to assess and verify vehicle designs for radiation protection
- Assessment of technology developments for monitoring radiation exposure and recommendations on technologies to be used operationally
- Reduction of uncertainty in risk projections to enable design for radiation protection and crew constraints for all exploration missions
- Development of physical or biological countermeasures and assessments of their effectiveness

The results of space radiation studies contribute to human exploration by providing the scientific basis to accurately project and mitigate health risks from space radiation. Research in radiobiology and physics guides and supports risk assessment and protection strategies. The results will provide tools for evaluating shielding recommendations for habitats and vehicles as well as requirements for storm shelters and early warning systems for solar particle events. To read more about the Space Radiation Element, please visit: spaceradiation.usra.edu

Cancer Risk Projection Model

Exposure to solar particle events and GCRs pose cancer risks to astronauts. In FY2010, radiation personnel updated NASA's Cancer Risk Projection Model and evaluated the uncertainties that factor into risk quantification, which is needed to evaluate astronaut compliance with PEL. The projection model originates from recommendations of the National Council on Radiation Protection and Measurements and includes revisions from the latest analysis of human radio-epidemiology data.



The model provides seamless integration of input and output manipulations, which are required for operations of the sub-modules and the cancer probabilistic response model. The Graphical User Interface (GUI) of the model is the integration of various components in the cancer risk projections for human space applications. The main applications envisioned are ISS missions and planning for future exploration missions. The updates to the model are being reviewed by the National Academy of Sciences. A beta test version has been distributed to solicit user feedback.

ARRBOD Acute Risk Projection Model

The space radiation environment, particularly solar particle events (SPEs), poses the risk of acute radiation sickness to humans. Organ doses from exposure to SPEs may reach critical levels during extravehicular activity or within lightly shielded spacecraft. Radiation personnel have updated the Acute Radiation Risk and BRYNTRN Organ Dose (ARRBOD)



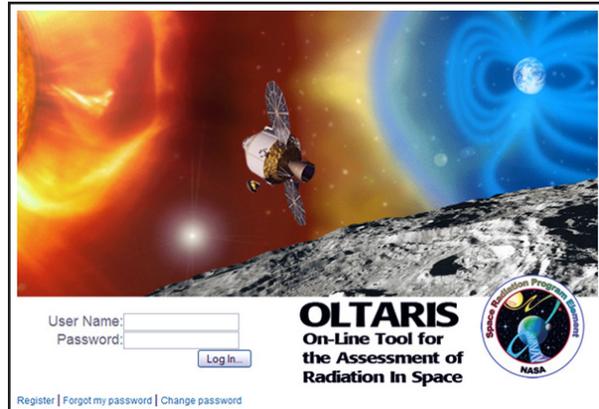
Projection GUI as a new self-contained product and will have follow-on versions as options are added.

The model and interface are described in the technical publication NASA/TP-2010-216116, which is available through the online Langley Research Center Scientific and Technical Information Program. This publication describes the organ dose projection model and a probabilistic model of acute radiation risk, both developed by NASA. The ARRBOD GUI is intended for mission planners, radiation shield designers, space operations personnel, and space biophysics researchers. The major components of the overall system are described in this publication and the product is explained in a step-by-step tutorial.

Baseline OLTARIS Design Tool

Radiation personnel develop and maintain an integrated tool set that collects the current best practices, databases, and state-of-the-art methodologies to evaluate and optimize space radiation protection for human systems such as spacecraft, spacesuits, rovers, and habitats. The On-Line Tool for the Assessment of Radiation in Space (OLTARIS) radiation design tool website was significantly enhanced in FY2010 to include updated light ion and neutron transport, multi-layer transport in user-specified materials, the calculation of back-scattered neutrons, and voxel-based human geometry models to more accurately calculate effective dose.

These accomplishments establish the basis for ray-by-ray transport with backward and forward neutron generation within spacecraft and lunar surface geometries, to provide for a more accurate simulation of the primary and secondary radiation spectrum within the spacecraft and critical body organs. The tool set has been baselined with successful independent verification and validation utilizing design test cases, shuttle, and ISS measurements. In addition, full online documentation exists and follows NASA Standard 7009, Standard for Models and Simulations. The tool set can be accessed through the OLTARIS website: <https://oltaris.larc.nasa.gov>



During this fiscal year, several enhancements were made to the on-line OLTARIS tool to establish baselines for both shuttle and station radiation levels.

NASA Space Radiation Laboratory (NSRL) at Brookhaven National Labs

Ground-based research in radiobiology is conducted for NASA at the NSRL, using beams of high-energy heavy ions simulating the space radiation environment as well as the solar particle events simulator



The new automated entry system allows for easier, safer access to the NSRL beam line room for personnel and equipment.

and large beam capability. To develop accurate models of the risk to exploration crews of radiation-associated health effects and to identify countermeasures for reducing those risks, NASA investigators participated in three campaigns at the NSRL in FY2010. During these campaigns, more than one hundred experiments to irradiate a variety of biological specimens, tissues, and cells during a total of ~1,050 hours of beam time yielded valuable data. The results are published in numerous peer-reviewed scientific publications such as *Radiation Research*, *Nature Reviews Cancer*, and *The Lancet Oncology*.

Also in FY2010, a new automated entry system was commissioned, ensuring safe and easy access to the beam line with a time reduction of 20 percent from previous methods. In addition, the Electron Beam Ion Source (EBIS), co-funded by the Space Radiation Element and the Department of Energy's Office of Nuclear Physics, successfully passed Criti-

cal Decision-4, Operational Readiness and Project Close-out Review. The EBIS was successfully used during test runs in 2010, and will be fully available in 2011. It provides a larger array of ion species at higher beam intensities than were previously available, with greater operational flexibility and the potential for real-time GCR simulation.



An NSRL researcher places a sample into the beam line for exposure. Researchers employ beams of heavy ions extracted from Brookhaven's accelerator to simulate the effects of cosmic radiation.



Overview

NASA uses the term “countermeasures” to describe the procedures, medications, devices, and other strategies that help keep astronauts healthy and productive during space travel and return to Earth. The Human Health and Countermeasures (HHC) Element is responsible for understanding the normal physiologic effects of spaceflight and developing countermeasures to them. Before they are tested during flight, candidate countermeasures and technologies are developed and refined using ground-based studies and flight analog environments. An analog is a concept or situation that in some way resembles a different situation. Example analog environments include head-down-tilt bed rest, undersea habitats and Antarctic outposts.

The HHC comprises five projects that address exercise, non-exercise, and extravehicular activity (EVA) countermeasures and provides flight analog facilities and computational modeling to help test and integrate potential countermeasures before flight verification. Major FY2010 accomplishments of these projects are reported below in their respective sections: Exercise Countermeasures, EVA Physiology Systems and Performance, Flight Analogs, and Non-Exercise Physiological Countermeasures.

To learn more about the HHC, please visit www.nasa.gov/exploration/humanresearch/elements/research_info_element-hhc.html

Exercise Countermeasures Project

Overview

The Exercise Countermeasures Project (ECP) is responsible for developing effective, efficient exercise protocols and hardware to maintain astronaut health and fitness during long-duration space missions and to preserve the capability to perform mission-critical tasks both in transit to another planetary body and while on the planetary surface. The ECP conducts ground, spaceflight analog, and flight studies to address risks and knowledge gaps. Additionally, the ECP sponsors research that will guide the Human Spaceflight Medical Standards that relate to muscle and cardiovascular health.

Exercise Capabilities for the Space Exploration Vehicle

For the 2010 Desert Research and Technology Studies (RATS) 14-day field trial of the prototype Space Exploration Vehicle, formerly called the Lunar Elec-

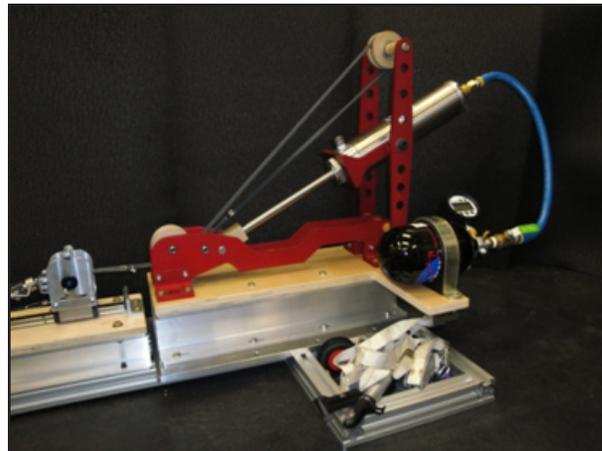


The prototype SEV ergometer was field tested during the 2010 Desert RATS. It allows crewmembers to exercise while generating power.

tric Rover, the ECP provided two compact exercise concept devices: a cycle ergometer with power-generation capability, and a gas-spring resistance device with load-adjust capability of up to 430 lbs. of resistance. The devices were used in each of the rovers in the field analog, for human factors and habitability assessment.

The ergometer provides aerobic exercise in a compact stationary cycle, and upper body resistance. While requiring no vehicle power to operate, the ergometer actually delivers power when it is used in either of two modes. The power can be stored, or used to power a device like a laptop computer.

The gas spring resistive exercise concept device also requires no power, and is charged with a simple, compact air-rifle pump to any desired load resistance setting. Changing the cable configuration makes it possible to do a variety of exercises including: pull-



The Lunar Electric Rover Gas Spring resistance concept device weighs only 22 lbs. and can generate up to 430 lbs. of resistance with infinite adjustment.

downs, dead lifts, bicep curls and squats. Findings from the human factors assessment of these concept devices during the field trial are in work.

Functional Task Test

To further understand the relationship between astronaut postflight functional performance and related physiological changes, a study was conducted by the ECP entitled “Physiologic Factors Contributing to Postflight Changes in Functional Performance.” This study is also known as the Functional Task Test (FTT).

The FTT is an interdisciplinary protocol that maps cardiovascular, neuromuscular, and sensorimotor responses to performance of mission-specific functional tasks. Functional tasks are based on expected exploration mission activities such as ladder climb, hatch opening, jump down, construction activity board, seat egress and obstacle navigation, recovery from fall, and object translation simulations. Performance data are collected during simulations of these mission tasks as well as before and after shuttle and ISS missions. Results from this study are expected to inform development of targeted countermeasure protocols to mitigate these changes and maximize crew health and performance.



An FTT subject performs the ladder climb, object translation, and construction board task simulations (from left to right) while instrumented with test hardware.

To date, FTT data has been collected from the STS-128, 129 and 131 crews. A significant milestone was reached with the completion of data collection from the first long-duration FTT crewmember and subsequent long-duration testing will occur with the return of Expeditions 24-26.

To complement the FTT flight study, the influence of alterations in muscle strength, power, and endurance, relative to body weight, were evaluated in an ECP “weighted suit” ground evaluation. This study lays the groundwork for the development of functionally relevant strength thresholds required for astronaut occupational performance. The FTT team was recognized for their integrative and innovative efforts with a JSC Director’s Innovation Group Achievement Award in May 2010.

NSBRI – Monitoring Bone Health Using Daily Load Stimulus During Lunar Missions

When the human body is subjected to either long-durations of microgravity or continuous bed rest, a series of cascading events occur resulting in muscle atrophy and a 1-2 percent loss per month of lower-extremity bone mineral density. An NSBRI study was initiated to evaluate whether lunar gravity and the EVA tasks that occur during a normal lunar

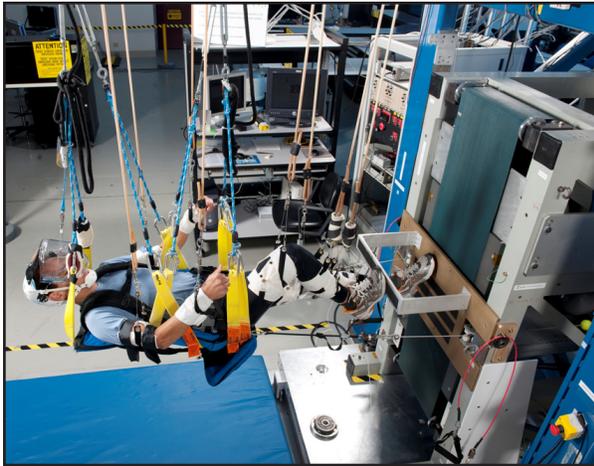
workday will offer the mechanical stimulus or “dose” of load to the lower extremities that will maintain skeletal integrity.

Major accomplishments this year include development of lunar gravity task simulation hardware and methodologies derived from the FTT. Additional accomplishments include completion of the ground phase of this study and development and evaluation with a wireless accelerometer-based system.

EVA Physiology, Systems, and Performance

Overview

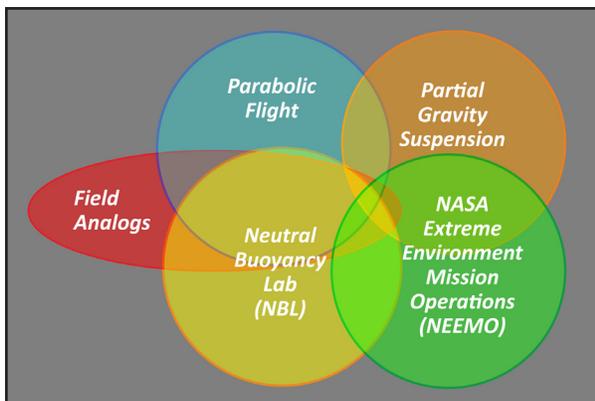
Performance of EVA consists of placing a human in a micro-environment, which must provide all the life support, nutrition, hydration, waste, and consumables management functions of an actual space vehicle, while allowing crewmembers to perform in an environment as close as possible to a one-g shirtsleeve environment. In FY2010 the EVA Physiology Systems and Performance (EPSP) Project continued its cross-disciplinary work to understand the effects of EVA suit system design and operations on human performance and safety.



A test subject performs the ladder climbing activity in simulated lunar gravity and is outfitted with miniaturized accelerometers to examine the effect on the daily load stimulus.

Suit Parameter Design Requirements for EVA Suit Configuration-1 PDR

EPSP has designed and executed a series of human performance evaluations in multiple analog environments. Certain aspects of each analog provide insight into human performance in partial gravity, but each has its limitations. For example, parabolic flight provides true partial gravity, but only for a short time; partial gravity suspension provides the most controlled testing environment for various gravity levels, even though the subject is suspended, the limbs are still moving through space in a one-g environment.



The EPSP Project pools data from several analog environments to establish a more complete set of parameters for EVA suit design.

By combining the data from several analogs, a more complete picture of human performance in partial gravity is obtained and can be used to develop requirements for EVA suits that optimize crewmembers' ability to safely and efficiently perform critical mission tasks.

Analyses of the Integrated Suit Test (IST) series were completed and approved and the suit parameter recommendations were delivered in a set of NASA Technical Reports. Two additional reports have been submitted for internal NASA review and will be published in early FY2011.

Development of a Predictive Algorithm to Estimate EVA Suit Consumable Levels

Metabolic rate is an established parameter used in the calculation of life-support consumables such as oxygen, carbon dioxide clearance, and feedwater. For example, postflight analysis of Apollo mission data showed that Apollo astronauts experienced several "close calls" in which levels of EVA suit consumables were at unacceptably low levels.

Early in the Constellation Program, suit designers consulted with the EPSP Project to determine the best means to use metabolic rate and other biomedical sensors to provide important data on EVA suit consumables use. The information was then developed into a requirement in the Human Systems Integration Requirements Document.

The EPSP project developed a bioadvisory algorithm technology demonstrator, which has been implemented into suited human performance tests conducted in partnership with the Constellation EVA Systems Project Office (ESPO) Testing and Facility group. An intent of the demonstrator was to put into practice metabolic rate calculation methodology using sensor driven data to ensure the validity of the metabolic rate calculation methodology and to characterize the sensitivity and sensor requirements associated with these metabolic rate calculation methods. Preliminary data indicates that the

algorithm performs as intended, but further tests will be necessary and will be incorporated as additional objectives into future suit testing.

A functional specifications document was provided to the ESPO Technology Development Office in February 2010. The document provided specific detail regarding the metabolic calculations performed by the algorithm and a list of the necessary sensors. The document represents the EPSP project recommendations for methods of metabolic rate calculations to support the Constellation Program EVA Suit Element Power, Communication, Avionics, and Informatics Subsystem development of hardware and requirements. These recommendations are preliminary because of the limited fidelity of the current exploration architecture, EVA suit systems, and operational concepts that will require physiological monitoring. However, they represent the best recommendations of the EPSP project to-date and will be updated as more information is known.

Non-Advocate Review of Risk of Decompression Sickness During Lunar Surface Operations

As NASA's future for human exploration expands beyond low Earth orbit, life-support systems for spacecraft and EVA suits will need to be scaled appropriately for available resources, mission operations, and atmospheric composition. These tradeoffs may pose a greater risk of decompression sickness (DCS) for the EVA crewmember if parameters such as prebreathe duration, oxygen concentration, or suit pressure are altered from those NASA has used in the past. As a result, anticipated atmospheric conditions for exploration vehicles and EVA suits will require careful evaluation for their potential risks to the crew.

As part of an effort to establish the risk of DCS during exploration missions, EPSP commissioned a panel of external experts to review the risk of DCS for lunar missions and provide recommendations regarding the likelihood and consequence of the



Lunar EVA conditions may be more stressful than current Shuttle or ISS conditions, which could increase the risk of decompression sickness (DCS). Further studies are recommended to evaluate the risk of DCS in these scenarios.

risk and any applicable forward work to understand and mitigate the risk. The panel was instructed to review a set of proposed lunar mission scenarios and timeframes for which DCS may be a risk: acute health, trauma during launch and landing, impact on mission operations, and post-mission long-term health concerns.

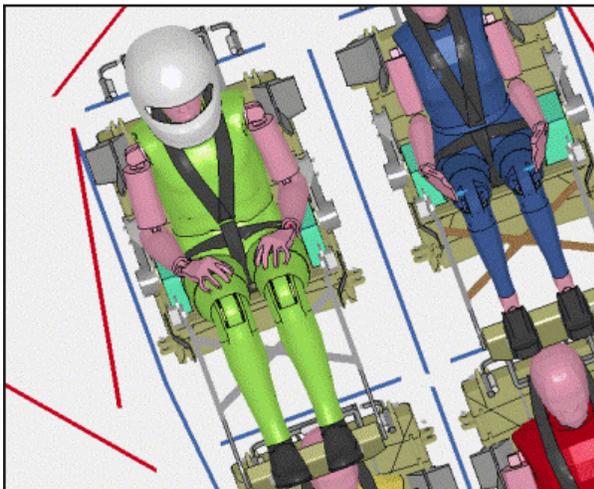
In June 2010, EPSP provided the panel a tour of JSC facilities in which DCS research is conducted and were given materials for their review. The panel provided their recommendations in late August, and EPSP is working to incorporate these recommendations into a systematic research plan to understand and quantify the risk of DCS during exploration missions.

Occupant Protection, NASCAR Crashes, and Analysis of Probability of Injury Curves

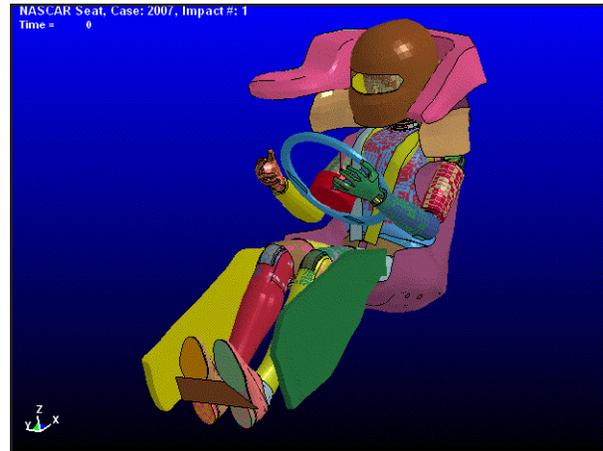
As the mission of NASA evolves to incorporate commercial crew vehicles, the role of the Occupant Protection study is to develop the crew protection landing impact standards. Important steps toward developing these standards were accomplished in FY2010. The EPSP team continued its efforts to document and objectively quantify the risk of crew injury during landing and to identify the specific aspects that most contribute to the risk, establishing

both the “Risk of Landing Impact Injury” and the Operationally Relevant Injury Classification Scale for use in classifying injuries based on their severity, operational impact, and long-term crew health.

Development of crew protection standards also necessitates defining the range of acceptable injury risk. The Occupant Protection team held a summit in January 2010 to address the Definition of Acceptable Landing Injury Risk. The goal of this meeting was to formulate a recommendation for an acceptable level of injury risk associated with NASA spacecraft landing scenarios. The meeting assembled an expert panel of biomechanics, occupant protection, and injury biodynamics experts from auto racing, academia, and military occupant protection design backgrounds. Representatives included numerous NASA stakeholders. The panel reached consensus on the recommendation for an acceptable level of injury risk categorized by a four-point injury classification system. This recommendation embodies the team’s position that crew injury risk is best evaluated by an assessment that includes a classification of injuries from minor to life-threatening. At the end of FY2010, this recommendation was accepted by the JSC Space Life Sciences Directorate. A review by other NASA stakeholders is pending.



In collaboration with the Constellation Program, the Occupant Protection Team used finite element modeling to evaluate the risk of crew injury during Orion landing scenarios.



The Occupant Protection Team modeled and analyzed more than 4,000 NASCAR crashes, and then developed a tool to predict the probability of head injuries during impacts. The results will improve crew safety on future missions.

The Occupant Protection team continues refinement of its biodynamic models that will be used by NASA to evaluate and certify a variety of hardware, seat, and restraint designs for future spacecraft. In doing so, the team has collaborated extensively with the automotive and racing industries as well as the commercial and military aviation fields. These partnerships provide NASA with two key benefits. First, knowledge of safety and regulatory practices used for similar occupant protection systems, and second, the development and improvement of the NASA approach to injury prediction and analysis.

An analysis of the National Association for Stock Car Auto Racing (NASCAR) crash database was completed with a total of 4,071 impacts analyzed and modeling completed for 274 of these cases. The model responses were compared with actual injury data and analyzed to determine the probability of head injuries. These results can be applied to NASA requirements and standards to improve safety for NASA crews on future NASA spaceflight vehicle designs.

Using the methodology developed with the NASCAR analysis, the Occupant Protection team will work to build a Human Impact Injury Data-

base. By incorporating additional injury and human tolerance data from other sources, NASA can define human tolerances in the unique conditions expected during spacecraft landings. This data will be gathered through existing partnerships from previous military research projects and additional tests in the upcoming year. When completed, this will provide NASA with the most accurate biodynamic models available for the prediction of injuries during spaceflight return landings and other dynamic flight phases.

Human-in-the-Loop Evaluation of New Gimbal Harness

During the Integrated Suit Test series, a key lesson was learned regarding the gimbal and harness spreader-bar assemblies which are used to connect suited and unsuited human subjects to the overhead suspension systems. The current hardware has significant limitations that may negatively affect the data collected. EPSP worked with JSC Engineering Directorate personnel to design new systems to minimize these limitations.

The newly designed gimbal will be used for unsuited testing with the Active Response Gravity Offload System (ARGOS), which currently supports subject weights of up to two hundred fifty pounds. Unlike the previous assembly, this design provides rotation through all three degrees of freedom (roll, pitch, and yaw) and allows for these axes to be aligned with the system center of gravity.

These improvements should have a significant impact allowing for realistic movements leading to more accurate human performance data. To determine the feasibility of using this new gimbal and harness for future human performance tests, human-in-the-loop evaluations were conducted in the newly built and certified overhead suspension system.

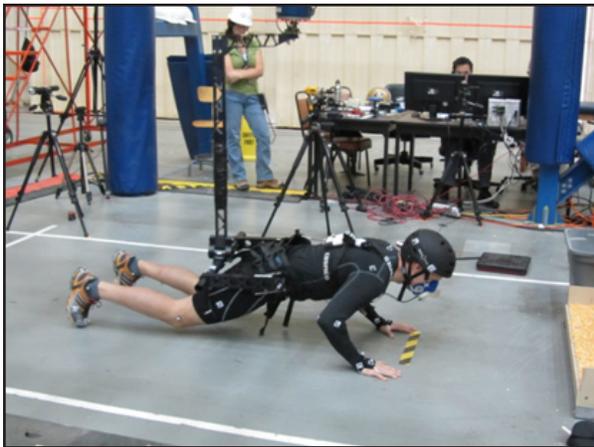
The purpose of these evaluations were to determine proper methods of positioning subjects within the system, a standard way of recording data, evaluating the human factors associated with using the gimbal



A subject tests the improved gimbal-harness on the ARGOS, an overhead suspension system used to simulate microgravity, lunar and Mars gravity.

and harness and to verify the use of the system with a wide range of body sizes. Finally, the tests assessed whether subjects could successfully accomplish a series of simulated EVA tasks.

Ten subjects ranging in height from 5'3" to 6'4" and one hundred twenty to two hundred thirty pounds participated in the evaluation. During the test session, each subject performed a series of ambulation and exploration EVA tasks, including jumping, lunging, incline walking, running, picking up and transferring objects, shoveling, and prone position and recovery to standing.



A new gimbal-harness significantly improved subject mobility in lunar gravity simulations.

Overall, the evaluation demonstrated that the gimbal performed acceptably for all subjects once it was properly adjusted. The results of this evaluation have established the groundwork for the development of tests to determine human performance capabilities in the new ARGOS. These enhancements will provide a better understanding of human suited performance across a range of EVA suit characteristics, tasks, and the various gravity levels expected during exploration missions.

Non-Exercise Physiological Countermeasures

Overview

The Non-Exercise Physiological Countermeasures (NxPCM) Project addresses cardiovascular, immunological, skeletal, nutritional, pharmacological, and neurovestibular or sensorimotor physiology in an operationally driven research program seeking to understand and, if possible, mitigate spaceflight human health and performance issues. During FY2010, the project research portfolio contained twenty-three ongoing flight and ground research studies performed by intramural and extramural investigators across the six physiologic disciplines.

Stability of Pharmaceuticals in Space

In November of 2008 the final “Stability of Pharmaceuticals and Nutrients in Space” study kit was returned on STS-126 after a 28-month stay on the ISS, having been launched on STS-121 in 2006. The pharmaceuticals payload for the Stability study included four identical pharmaceutical payload kits containing thirty-one medications in different dosage forms such as injectable liquids, pills and ointments. Environmental monitoring of the kit indicated that mean temperature and humidity were comparable on the ground and in space. However, cumulative radiation levels were significantly higher in space and increased as a function of time.

The results from the study were submitted to the journal of *The American Association of Pharmaceutical Scientists* for review before publication. Results indicated that a number of medications did not meet one or more United States Pharmacopeia (USP) stability criteria after spaceflight compared to their respective ground controls. A small number of pharmaceuticals were stable beyond their expiration dates, however, the number was greater for the ground control than the flight medications. This indicates the shelf life of pharmaceuticals in space may be compromised. Factors affecting the stability of pharmaceuticals may include vibration, cumulative radiation dose, and repackaging of dosage forms from their original commercial dispensers.



The Stability flight investigation evaluated pharmaceutical samples. The kits contained 31 medications in different dosage forms.

Flight Analogs Project

Overview

The Flight Analogs Project (FAP) supports a variety of investigations using ground-based bed rest analogs. Bed rest is a well established spaceflight analog to study changes in physiologic function associated with reduced gravity and spaceflight. A battery of biomedical tests, called standard measures, are conducted on each subject to assess immune function, nutritional status, cardiovascular responses, exercise responses, neurological function, and bone physiology before, during, and after bed rest. The Flight Analogs Project also supports coordination of human research participation in ground-based missions for other analog environments such as the NEEMO Aquarius facility in Florida; the Haughton-Mars Project in Devon Island, Canada; research stations in Antarctica; and Desert Research and Technology Studies in remote areas of Arizona and California.

Gender Differences (Campaign 3) Bed Rest Study

FAP personnel completed operations for the Campaign 3 study entitled “Gender Differences in Bed Rest: Autonomic, Neuroendocrine, and Vascular Responses in the Lower and Upper Extremities.” The objective of this study was to determine which



Subject participating in the Gender Differences Study in the common area at the UTMB Flight Analog Research Unit.

cardiovascular attributes contributed to the difference in incidence of orthostatic intolerance between genders. Female astronauts exhibit greater orthostatic intolerance than their male counterparts. The 6 degree head-down-tilt bed rest model was used to induce cardiovascular changes that were similar to spaceflight for the purpose of studying the mechanisms responsible for orthostatic intolerance.

Twenty-three subjects participants were admitted to the NASA Flight Analogs Research Unit located at the University of Texas Medical Branch in Galveston, Texas. In the first phase of the study, participants were free to move about the facility and baseline testing was completed. In the next phase, long-duration bed rest, participants were placed in bed and tilted in a 6 degree head-down position for sixty or ninety days. Participants remained in this position for all activities including testing and hygiene.

For the final phase of the study, participants were able to move freely about the unit while they received rehabilitation and post-study testing. Participants were evaluated using the Flight Analogs Project battery of standard measures which provides a multidisciplinary physiological assessment of each participant in the study. Orthostatic tolerance was evaluated before and after long-duration bed rest. Vascular responses, cardiac function, and body fluid dynamics were measured throughout the study to examine changes related to bed rest.

Results of this study will provide critical information to assess the mechanisms of orthostatic intolerance in men and women. From this information countermeasures will be developed to offset the cardiovascular effects of spaceflight and preserve orthostatic tolerance.

30-day Head-Down-Tilt Bed Rest Study

This bed rest study incorporated investigations of four scientists which enabled the same subject sample to be used by all investigators in an effort



Subject enjoying in-room activities while in the 6 degree head-down tilt phase of the study.

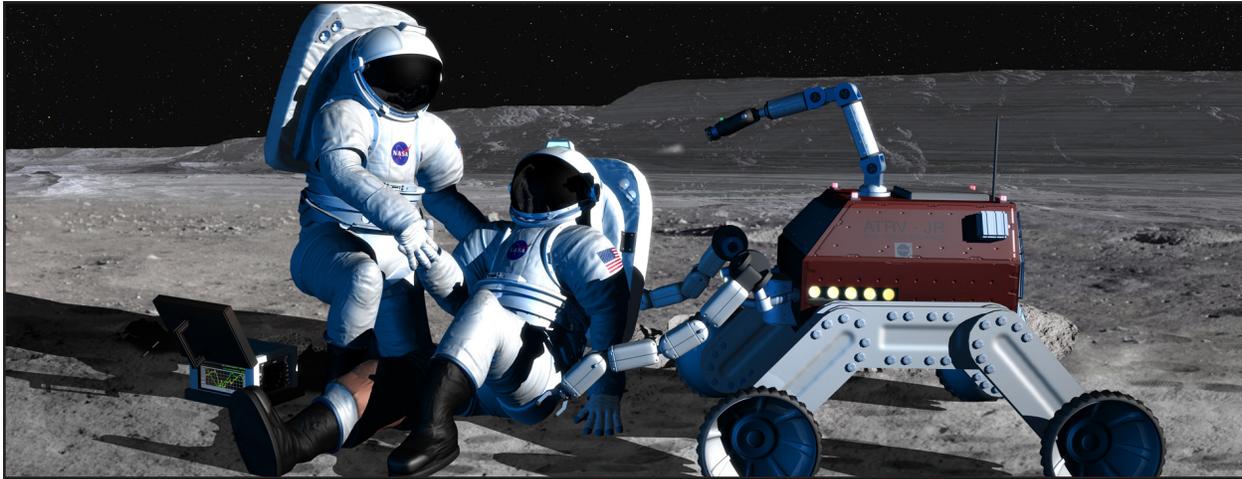
to more efficiently complete the research. A total of twelve participants completed thirty days of 6 degree head-down-tilt bed rest for this study. Upon admission to the NASA Flight Analogs Research Unit, participants completed two weeks of pre-bed rest baseline testing. This was followed by the thirty-day head-down-tilt bed rest period. After the bed rest phase, participants spent two weeks in post-bed rest testing and rehabilitation.

The first of the four investigator studies was titled “Rapid Measurements of Bone Loss Using Tracerless Calcium Isotope Analysis of Blood and Urine.” In this study, calcium isotope composition in blood and urine samples was used to develop methods for early detection of changes in bone mineral balance.

A second study integrated into this campaign was “Validation of Near Infrared Spectroscopy (NIRS) Measures following Bed Rest.” For this study, the NIRS device was validated as a noninvasive method to continuously measure oxygen consumption during cycling exercise to maximal effort.

During these same cycling exercise sessions, participants also took part in a third study “Non-invasive Device for Measuring Core Temperature during Maximal Exercise.” This study examined a noninvasive method using a double sensor placed on the head and chest to assess core temperature of the body during exercise.

The fourth study in this campaign was “Methods for the Assessment of Gastrointestinal Physiology and Function in a Reduced Gravity Analog.” Gastrointestinal function was assessed using “smart pill” technology. Participants ingest a special capsule containing sensors that monitor pH, temperature, pressure, and transit time throughout the gastrointestinal tract.



Overview

Human exploration of the Moon, Mars and other destinations beyond near-Earth orbit will present significant new challenges to crew health. During exploration missions, the crew will need medical capabilities to diagnose and treat injury or disease. Providing capabilities that overcome these challenges requires new health care systems, procedures, and technologies to ensure the safety and success of exploration missions.

The Exploration Medical Capabilities (ExMC) Element develops medical technologies for in-flight diagnosis and treatment; data systems that protect patients' private data; aid in the diagnosis of medical conditions and act as a repository of information about relevant NASA life science experiments.

ExMC physicians and scientists develop models to quantify the probability of medical events occurring during a mission. They also define procedures to treat an ill or injured crewmember without access to an emergency room and with limited communications with ground-based personnel for consultation and diagnostic assistance.

Validation of "Braslet-M" for the In-Orbit Assessment of Cardiac Function

The study "Validation of On-Orbit Methodology for the Assessment of Cardiac Function and Changes in the Circulating Volume Using Ultrasound and Braslet-M Occlusion Cuffs" was a collaborative effort between NASA and the Russian Space Agency. This investigation established an ultrasound methodology for assessing aspects of central and peripheral blood flow and cardiovascular function, specifically rapid changes in intravascular circulating volume. The Russian-made Braslet-M occlusion cuff system and cardiopulmonary maneuvers were used to demonstrate and evaluate the degree of changes in the circulating volume on orbit.

From December 2007 to June 2009, nine subjects participated in a total of fourteen data collection sessions. Multiple modes of ultrasound imaging were used to perform measurements without the Braslet, with Braslet applied, and during release of the device. The data showed significant changes occurred in several cardiovascular variables as a result of Braslet use.



An ISS crewmember uses ultrasound to monitor cardiac and vascular function while wearing a Braslet-M thigh occlusion cuff.

The project demonstrated that minimally trained astronaut operators can perform complex cardiovascular examinations using the training, remote guidance, and scanning techniques developed during this study.

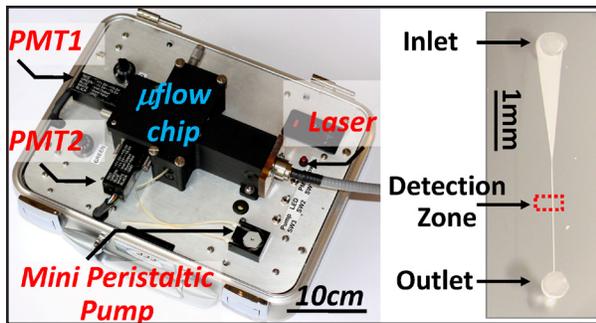
The final report was completed in September 2010. These techniques can be broadly applied to remote medicine including military applications, austere environments, and underserved areas.

Requirements Baseline for Exploration Biomedical Sensor and In-flight Lab Analysis

NASA frequently flies redundant sets of devices for the research and medical operations communities. This redundancy is the result of differences between the requirements for the range of analyses, measurement sensitivity, certification, and criticality. However, the extreme mass, volume, and power constraints of exploration missions suggest that the approach

of separate devices be re-evaluated. During FY2010 two requirements documents were developed to start an ongoing effort to consider the potential for synergy and shared capability between the research and medical operations communities.

The requirements document for the Intra-vehicular Activity Physiological Monitoring System (IPMS) captured shared requirements for measurement of parameters including heart rate, electrocardiogram (ECG), body temperature, respiratory rate, blood pressure, and blood oxygen saturation. A shared requirements document for the Exploration Medical Laboratory (EML) was also developed. The EML will consist of one or more instruments which provide biomedical diagnostic capability to facilitate the recognition and treatment of several medical conditions. Functional requirements for the IPMS and EML were submitted for critical review. These two requirements documents will provide guidance for the development of current and future biomedical



Using requirements gathered by the space medical community, a shared blood-analysis system similar to the prototype above will perform multiple blood tests within one device.

hardware to ensure that instrumentation meets the demands of future space exploration medical operations and research.

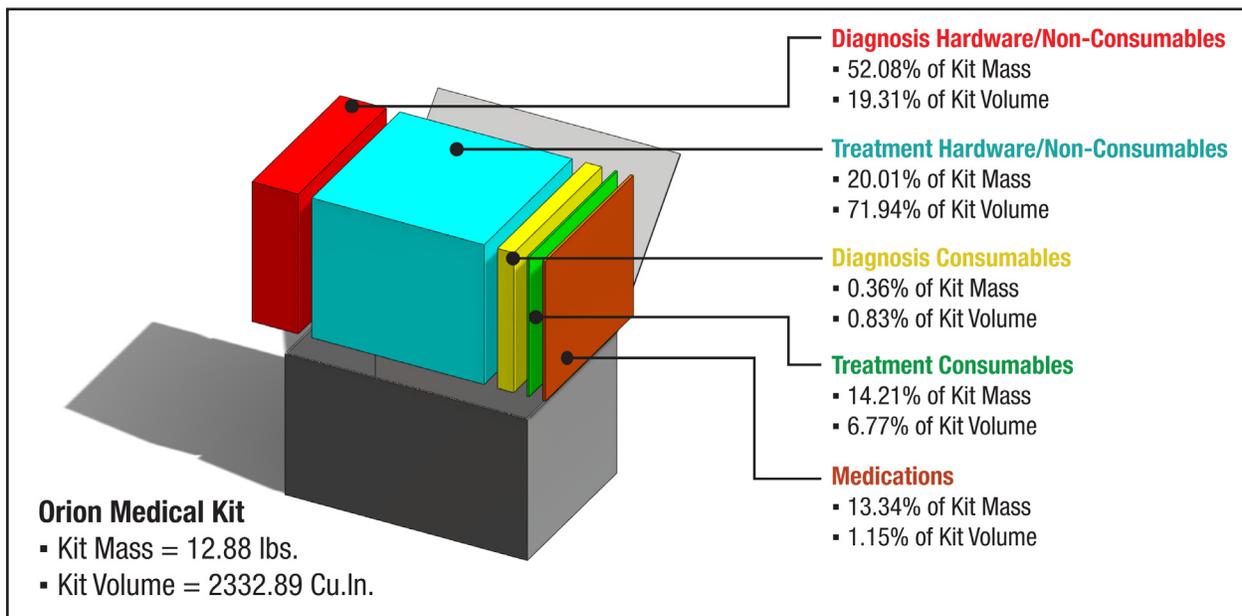
Orion Medical Kit Analysis and Recommendations

ExMC personnel developed a list containing all of the medical conditions of concern for an Orion vehicle mission. This list, called the Space Medicine Exploration Medical Condition List (SMEMCL),

was used to generate prototype medical kits to diagnose and treat conditions defined within the SMEMCL.

The Integrated Medical Model (IMM), a model that simulates medical events during space flight missions and estimates the impact of these events on crew health and mission success, was used with the SMEMCL to create and objectively compare the prototype medical kits. The kits were compared by evaluating the risks associated with each based on the probable medical events for an Orion mission. Also taken into consideration was the ability of the crew to diagnose and treat medical conditions with the resources provided in each of the kits.

The mass and volume of the medical kit derived from the SMEMCL resources were compared with the original Constellation Program mass and volume allocation for the Orion medical kit. On the basis of the results obtained from the IMM and other analyses, it was recommended that a greater mass and volume allocation be requested.



A prototype Orion medical kit was developed based on the probable medical events for a 3-day transfer mission to the ISS.



Overview

The Space Human Factors and Habitability (SHFH) Element consists of three main project areas: Advanced Environmental Health (AEH), Advanced Food Technology (AFT), and Space Human Factors Engineering (SHFE).

The AEH project focuses on understanding the risk of microbial contamination of the spacecraft and on the development of standards for exposure to potential toxins, such as lunar dust. The project also provides environmental requirements, particularly for the atmosphere and water for spacecraft and space missions.

The AFT project focuses on reducing the mass, volume, and waste of the entire integrated food system for exploration missions, while investigating processing methods to extend the shelf life of food items for missions up to five years. The project also delivers improvements in both the food itself and the technologies for storing and preparing it.

The SHFE project establishes human factors standards and guidelines for human-machine interactions to ensure optimal productivity of the crew in both physical and cognitive interactions with hardware and software.

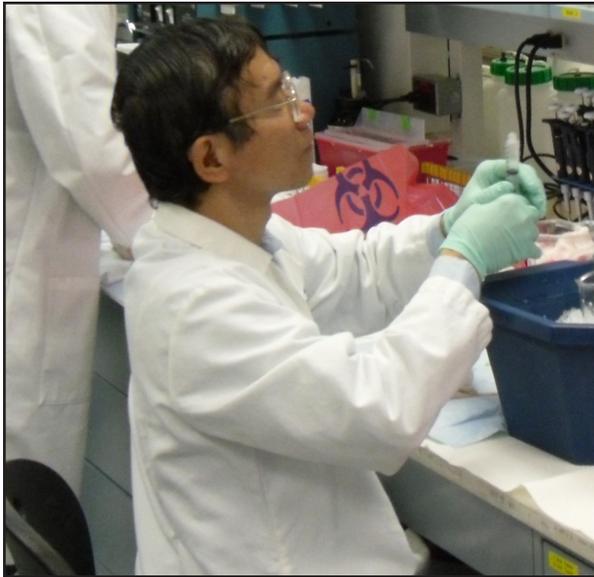
SHFE also provides validated models for predicting the effects of interface designs on human performance, methods for measuring human and human-system performance, and improved design concepts for advanced crew interfaces and habitability systems.

To learn more about SHFH, please visit http://www.nasa.gov/exploration/humanresearch/elements/research_info_element-shfh.html

Advanced Environmental Health Project

Overview

The Advanced Environmental Health (AEH) project is working toward answering important questions such as “How potentially toxic are lunar dusts?” and “Is the crew at greater risk of infection during a mission?” AEH-sponsored studies gather data that will be used to develop standards for air, water, and other life-support systems, which vehicle or habitat designs must meet. Data from AEH studies also drives the need for monitoring and personal protection hardware for missions to the ISS and exploration destinations.



A toxicology scientist studies lunar dust particles that are small enough to reach the innermost portions of the lungs

Lunar Dust Toxicity

The toxicity of lunar dust is being studied by NASA's Lunar Airborne Dust Toxicity Advisory Group. The working group consists of teams, including a geology and toxicology team, from the JSC and Ames Research Center (ARC) and from academia.

Studies of toxicity of airborne lunar dust require the use of particles that are small enough to reach the innermost portions of the lungs. The geology team developed a separation method using a stream of ultrapure dry nitrogen to remove the smaller, lighter particles from the larger ones.

The toxicology team conducted a pilot study at the National Institute of Occupational Safety and Health in which native lunar dust; lunar dust ground with a jet mill; or quartz dust, a highly toxic dust used as a positive control, were each applied to the respiratory tracts of rats. Fluid was later collected from the lungs and analyzed.

These findings were used to determine the doses for a core intratracheal instillation study in which rats were dosed with one of five materials which included

three types of lunar dust as well as positive and negative control dusts.

Final Water Sampling for the Surface, Water and Air Biocharacterization Study

The Surface, Water and Air Biocharacterization (SWAB) study was designed to provide a comprehensive characterization of pathogenic microorganisms and allergens residing in the ISS. Additional objectives of this flight experiment included an evaluation of the spacecraft's microbial ecology and preparation of molecular primers to facilitate microbial detection. The goal of these assessments was to define and mitigate crewmember risks from microorganisms during extended periods in space.

The study monitored hardware before launch and in-orbit by obtaining samples of water, surfaces, and air, which were then analyzed on Earth by means of advanced microscopy, molecular biology, and immunochemical approaches. SWAB air and surface sampling operations began during ISS Increment 13 in September 2006. Water sampling was completed in March and the final set of samples was returned in April 2010. Analysis is continuing and a final report is planned for completion in April 2011.

Advanced Food Technology Project

Overview

The AFT project is responsible for providing space flight crews with a food system that is safe, nutritious, and acceptable to the crew, while efficiently balancing appropriate vehicle mass, volume, waste, and food preparation time for exploration missions. This will require a packaged food system with a shelf life of 3 to 5 years – current shuttle and ISS food system technologies do not meet these requirements. Food not only provides nutrition for astronauts, but also enhances the psychological well-being of the crew by establishing a familiar element in an unfamiliar and hostile environment.



As part of the package configuration evaluation, a gusseted bag (right) was evaluated to replace the tray and lid design (left). The design has yet to be implemented.

Evaluation of Food Packaging

A total system approach is an operating system that considers each parameter of an overall process and seeks to optimize each of these parameters to maximize the total output. Exploration food systems require low mass, high quality, and long shelf life. Packaging failures, excess material, or oxygen trapped within the package can be detrimental to this system. To determine which packaging parameters can be modified to influence food system mass and food shelf life, an evaluation of package sealing conditions, seal width, vacuum flush procedures, and package configurations was conducted.

As a result of the evaluation, changes have been implemented in the ISS provisioning processes. Minimum temperatures were determined for optimum sealing of pouches and rehydratable packages. Improved vacuum flush settings were also identified and implemented as a result of the study.

During the package configuration evaluation, a gusseted pouch was designed to replace the current tray and lid design. The design change itself did not significantly affect the mass, but would enable a change in film material to save about 200 grams per container and decrease packaging time by 66 percent.

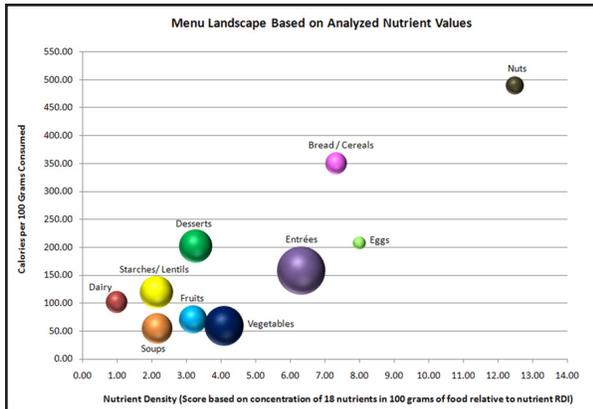
Trade Study – Food Processing vs. Packaged Food System

The current crewmember diet is completely supplied through prepackaged, shelf-stable food items produced on Earth. The duration of future missions may require a portion of the diet to be grown, processed, and prepared in the space habitat. To determine the degree to which food processing and a bioregenerative food system should be utilized on Mars habitat missions, a trade study comparing several bioregenerative and prepackaged menu scenarios is underway.

The scenarios for comparison were established during FY2010 using multiple food source combinations from farmed or shipped salad crops, bulk



African Sweet Potato and Peanut Soup, Flourless Peanut Butter Cookies, and Spanish Rice are three of the dishes incorporated into the 10-day menu cycle for food systems utilizing the bioregenerative and bulk ingredient food sources.



A graphic showing the nutrient and caloric density of food categories analyzed in the nutrition study. Nuts are clearly the most efficient in terms of nutrients and calories per gram.

crops, and prepackaged dishes. Three 10-day menu cycles with similar calories and nutrient intake were created. The food metric value (FMV) of each scenario will be computed and used for final analysis.

Analysis of the required mass of food associated with each system revealed that the food up-mass of the completely prepackaged food system was more than double the mass of the closest system despite the prepackaged system having a significant fraction of freeze-dried foods. However, equipment mass, volume, and power as well as crew time are also factors in the equivalent system mass calculations and subsequent FMV.

Over the next two years, the remaining factors will be evaluated and an informed recommendation will be provided to mission planners as to the optimum food system for long-duration habitat missions.

Effect of Processing and Subsequent Storage on Nutrition

Crewmembers rely on the foodstuffs provided through NASA to meet their nutritional requirements. Because vitamin degradation occurs with heat processing, oxidation, and light exposure, it is likely that the commercially sterile foods of the space program have reduced nutrient profiles at the time they are consumed. To evaluate the nutritional quality of

foods currently used for prolonged space missions, a study to examine the vitamin and mineral levels of space food after processing and long storage times of up to 5 years is ongoing. Food samples are analyzed for nutrient content immediately after stabilization processing and at 1 year and 3 years to understand storage impact.

During FY2010, twenty new foods were added to the ground study. Twenty-six food items underwent repeat analytical testing on the anniversary of their original stabilization processing. Incongruities in the estimates prevented researchers from drawing broad conclusions about vitamin stability during processing. A detailed look at some of the food products confirmed the following: degradation of some of the more sensitive vitamins; a chemical conversion which increases vitamin D; and manufacturers over-fortification of commercial beverage powders. This study will continue until 2012 and will analyze each of the NASA space food items.

Space Human Factors Engineering Project

Overview

The Space Human Factors Engineering (SHFE) project provides critical answers for the design of the next generation of NASA human spaceflight systems. To ensure that humans can perform exploration missions safely and effectively, SHFE scientists and engineers conduct studies in a variety of settings, from the laboratory to analog environments to spaceflight. They collect the information needed to verify that the crew's work environment, tools, and interfaces with complex systems support their tasks. The SHFE team works closely with design and space operations experts to ensure appropriate and timely solutions to their human-systems integration issues.

Acoustic Model Delivered to Orion Project

The Acoustics Modeling team has had several accomplishments during FY 2010. These accomplish-

ments included advancing the validation of acoustic modeling techniques, participating in a collaborative acoustic modeling effort on the Orion and Crew Module mockups, and identifying and validating specific noise controls for use in the Orion vehicle.

The acoustic modeling method was validated with respect to secondary structures such as closeout panels. In particular, the acoustic transmission properties of the Orion secondary structure partition that separates the crew habitable volume from the environmental control system's fans and pumps was modeled and mocked up with a realistic fan noise source located behind the partition. The predictions and measurements were in good agreement, thus validating the modeling approach.

A detailed acoustic model of the Orion Crew Module was also developed. This model was used to advocate the development of "system-level" noise treatments to aid in the global reduction of noise levels in the Crew Module. The benefit of this approach was to enable development of component noise allocations to meet the acoustic requirements.

Finally, the team made recommendations of noise treatments, specifically the acoustical sealing of gaps and the addition of acoustically absorbent treatments to some surfaces inside the Crew Module. This information, along with results from further trade studies in the modeling of noise control, acoustic investigations of flight materials, and implementation studies, was presented to management to obtain a mass budget of 35 lbs and hardware ownership of the noise treatments for implementation.

Usability Research: Development and Testing of a Maneuverability Assessment Scale

A number of objective and subjective human factors measures have been used to assess the fit and operability of the EVA spacesuit, including task completion times and errors, and workload and perceived exertion scales. Over the course of a large number of suit evaluations, it was noted that although objec-



Evaluation in the Neutral Buoyancy Laboratory at JSC, Houston, Texas: Crewmember responding to the Maneuverability Assessment Scale (MAS) in the Orion mockup

tive comments hinted at issues with ease of movement, none of the metrics directly measured the concept of maneuverability. Good maneuverability is required for moving from one place to another within a vehicle and in open spaces, and for interacting accurately with vehicle controls and tools. In FY2010, as part of the HRP Usability Directed Research Project, a maneuverability scale was developed and tested for use in evaluating ease of movement in both suited and unsuited in confined spaces such as crew quarters. The Maneuverability Assessment Scale (MAS) is a five-point scale, ranging from 1 – Excellent to 5 – Very Poor, that measures the ability to move in any direction with the desired pace and accuracy.

The MAS has been evaluated in several studies. An FY 2010 study evaluated factors affecting maneuverability with more than thirty participants in a task that involved donning and doffing a flight suit in an open laboratory setting and in an ISS crew quarters mockup. As a result of the study, a modified MAS was developed and field tested with six participants in an evaluation of removable hand rails for Orion at the JSC Neutral Buoyancy Laboratory.

Vibration Research

The past three years, HRP's Information Presentation Directed Research Project conducted a series



Participant in the Ames Research Center vibration chair using a prototype Orion Controller to perform CCD task.

of empirical studies that have focused on human visual and manual performance capabilities in severe vibration environments, such as would be expected on space launch. Astronauts' experience, along with data from these studies, supported the development of Constellation Program requirements on vibration limits. This design enables crews to visually monitor vehicle function during a vibration event and assume manual control after the event had ended.

In FY2010, data collection and analyses were completed for the final three vibration studies funded under the current Information Presentation Project. These studies investigated the relationship between differing types of whole-body vibration and their disruptive effects on display-reading performance and cursor control.

The first study indicated that the visual performance disruption caused by pulsed chest-to-spine vibra-

tion was commensurate with that produced by an equivalent constant vibration. The second study demonstrated the potential benefit of a generally applicable countermeasure technique for improving the readability of visual displays by observers undergoing whole-body vibration. The third study showed that although cursor control operation degraded as amplitude increased for single frequency chest-to-spine vibration, the pattern of the vibration effect was the same for each cursor control device (CCD). Cursor modes that were more constrained, such as those allowing only left to right movement, were more affected by vibration than other cursor modes.

The results of this work will help guide the design of human system interfaces for high vibration environments and aid in the formulation of performance-based requirements for future human space missions.



Overview

The Behavioral Health and Performance (BHP) Element conducts and supports research to reduce the risk of behavioral and psychiatric conditions. These include performance decrements due to inadequate cooperation and communication within a team and the risk of errors due to fatigue resulting from sleep loss or work overload.

BHP's strategy for addressing its risk reduction research is derived in a systematic manner and driven by operations. Spaceflight analogs and other research environments are carefully assessed to ensure that the individual, team, environment, and mission characteristics fit the research question at hand.

Long-duration missions, beyond low Earth orbit, will require crews to adapt to increasingly autonomous operations in isolated, confined, and extreme environments. Crews are faced with other challenges such as long periods of heavy workload, separation from home, and un-Earthlike day-night/light cycles. Microgravity, carbon dioxide, and radiation are other factors that may also lead to debilitating neurobehavioral and performance outcomes.

BHP is conducting operationally relevant research that will yield the deliverables, technologies, and rec-

ommendations to support the behavioral health and performance of astronaut crews and ground teams before, during, and after these exploration missions.

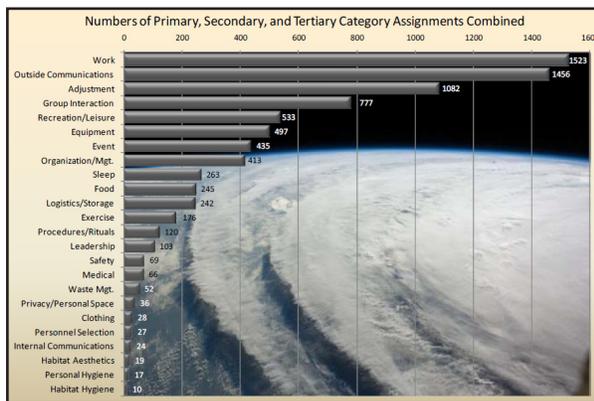
To address these risks, BHP categorizes research into three areas: Behavioral Medicine (B-Med), Team, and Sleep Risks. The B-Med Risk area aims to develop self-assessment tools for early detection and treatment that use unobtrusive and objective measures of mood, cognitive function, and other behavioral reactions to living and working in space. The Team Risk area examines team performance and other team-related outcomes including crew cohesion and communication, to develop tools and technologies that monitor teams throughout autonomous operations. The Sleep Risk area focuses on countermeasure development, including lighting protocols, medication recommendations, education, and tools that provide individualized work-rest schedules.

The end result is to provide technologies and tools that will optimize the adaptation of the individual and crew to the space environment, and maintain motivation, cohesion, communication, morale, well-being, and productivity.

Behavioral Issues Associated with Long-Duration Space Expeditions

The final report of the study “Behavioral Issues Associated with Long-Duration Space Expeditions: Review and Analysis of Astronaut Journals” which began in 2003, was completed in June 2010. The objective of the study was to identify relevant behavioral factors and obtain data to inform decisions about priorities of various behavioral issues, in order to prepare for future spaceflight missions. The report is based on what astronauts wrote about their experiences onboard the ISS for durations ranging from four to six months. This study provided the first quantitative data pertaining to the behavioral issues associated with long-duration spaceflight operations. A total of twenty-four issues were identified and rank ordered.

A large volume of data in the form of multiple journal entries was obtained. Data were coded first by chronological entries and quarters of mission duration, and then by major category and subcategory, and as positive, negative, or neutral in tone. Nearly all participants exceeded the minimum commitment, writing more frequently and candidly, with astronauts devoting a total of 705 sessions to the Journals Experiment. Questionnaires were administered before launch, at the midpoint of the mission, and after landing.



The Journals study provides unique insight into astronauts' day-to-day experience, as they work and live on the ISS.

The study found the crew wrote most about their work, followed by outside communications, adjustment to the conditions of spaceflight, crew interactions, recreation and leisure, equipment, events, organization and management, sleep, and food, in that order. Also, the study showed a decline in morale during the 3rd quarters of the missions. The entries and analyses provide a comprehensive description of ISS operations from the crew perspective.

Reaction Self Test on ISS

The Psychomotor Vigilance Task (PVT) is widely regarded as the optimal measure of fatigue for both laboratory and operational settings. The PVT detects changes in neurobehavioral performance involving vigilant attention, response speed, and impulsivity, and has been extensively validated in ground-based laboratory studies to detect cognitive deficits caused by a variety of factors, such as restricted sleep, sleep/wake shifts, motion sickness, and residual sedation from sleep medications. The PVT is an optimal tool for repeated use as studies have shown no-to-minimal learning effects and aptitude differences.

The inventor of the PVT, through the support of the National Space Biomedical Research Institute (NSBRI), BHP, and the Department of Homeland Security, has developed a three-minute version of the test that includes a feedback interface. The “Reaction



The Reaction Self Test has been validated extensively on the ground as an objective measure of fatigue. It is currently being validated in space.

SelfTest” was developed so that the PVT could serve as not only a data collection measure but also an operationally relevant tool, offering astronauts a quick way to assess their own performance acuity before they perform critical tasks.

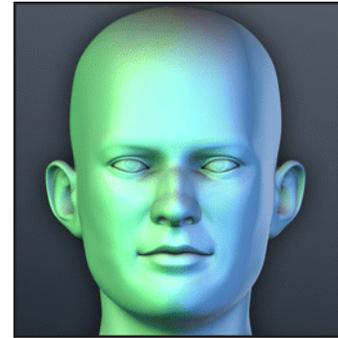
Sleep loss, schedule shifting, and heavy workloads are regular aspects of spaceflight. Evidence from studies on the ground shows that these factors, experienced by volunteers similar to astronauts and in doses similar to those in space, lead to performance decrements. The purpose of this investigation was to validate the Reaction SelfTest as a measure of fatigue-related cognitive performance during spaceflight.

Light Exposure, Circadian Rhythms and Sleep-Wake Scheduling

Space missions often expose crewmembers to unusual light-dark cycles that lead to misalignment between their circadian rhythms and sleep-wake schedules, resulting in disturbed sleep and impaired waking function. The NSBRI study “Characteristics of Light Exposure Necessary for Development of Optimal Countermeasures to Facilitate Circadian Adaptation and Enhance Alertness and Cognitive Performance in Space” is designed to address these issues. Sleep disturbances due to other reasons, such as noise, temperature, and microgravity, further exacerbate cognitive deficits, and these factors jointly increase the risk of fatigue-related accidents.

Light exposure facilitates more rapid adaptation of the circadian system and directly enhances alertness and performance. Research indicates that short wavelengths (blue) are the most effective for phase-shifting the circadian pacemaker, suppressing pineal melatonin, enhancing subjective alertness and improving performance. This investigation compared the effects of blue and green light on melatonin secretion at night. At the beginning of the study, green light and blue light were equally effective at suppressing melatonin. During the light exposure, however, spectral sensitivity to green light decayed relative to sensitivity to blue light.

These findings suggest that cone photoreceptors in the retina contribute substantially to nonvisual responses at the beginning of a light exposure and at low irradiances, whereas melanopsin seems to be the primary receptor in long-duration light exposure and at high irradiances.



Research has shown blue-enriched light can help alleviate jet lag and schedule shifting. Advances by NSBRI investigators indicate green light may also play a part.

Analog Assessment Tool

The Analog Assessment Tool is a systematic process developed by BHP to identify optimal analogs for conducting research. The tool utilizes an objective approach to determine the ideal analog for conducting research to address gaps in knowledge about BHP risks. The tool incorporates key factors such as the spaceflight scenario, the characteristics that are critical for addressing the gap, and the level of similarity between the space analog environment and the spaceflight mission. Through a ranking process, an order is established for addressing a specific risk.

The second iteration of the tool was completed in August 2010, and the final report was completed in September. Results provide prioritization of analogs by rating weights for each analog as well as an overall summary rating weight by BHP risk. The tool is flexible and can be adapted to meet user’s needs.



18th International Academy of Astronautics Humans in Space Symposium

The 18th International Academy of Astronautics (IAA) Humans in Space Symposium is an international scientific symposium dedicated to discussion and research in the human and biological sciences related to long-duration space travel. The symposium is scheduled for April 11-15, 2011, in Houston. Sponsoring organizations include HRP, the University of Houston, Universities Space Research Association, the National Space Biomedical Research Institute, Wyle Integrated Science and Engineering Group, and the University of Texas Medical Branch.

The theme of the symposium is “Integration and Cooperation in the Next Golden Age of Human Space Flight”. Highlights will include special sessions devoted to the 50th anniversary of Yuri Gagarin’s historic first manned space flight and the 30th anniversary of the first space shuttle mission.

The Local Organizing Committee is responsible for all aspects of planning, organizing, and implementing the Symposium. The Scientific Organizing Committee is responsible for planning, organizing, and carrying out all aspects of the scientific program. They are involved in screening abstracts, identifying platform and poster presentations, selecting keynote

speakers, selecting panel topics and participants, arranging the program, and selecting contributions for a special issue of *Acta Astronautica*, a journal published by the IAA.

The first part of the symposium will focus on daily themes which follow the sequence of a typical space flight mission: Pre-launch, Launch, Landing and Egress, Long-Duration Low-Gravity Transit and Extraterrestrial Surface Phase, and finally the Recovery and Rehabilitation Phase. The final day will be devoted to studies on – and design considerations for – the next generations of habitable space vehicles and extraterrestrial crew quarters.

Replacement Lighting for the International Space Station

The International Space Station (ISS) currently uses fluorescent General Luminaire Assemblies (GLAs) as its primary light source. It is anticipated that the supply of GLAs will be exhausted by 2015, therefore fluorescent-based GLAs will be replaced with new Solid State Light Assemblies (SSLAs) that provide illumination using which utilize white Light-Emitting Diodes (LEDs).



Astronaut Mike Fincke holds a prototype Solid State Lighting Module which will replace the older fluorescents on the ISS.

Representatives from the BHP Element and Space Medicine have noted that astronauts are regularly required to shift to a new time zone, or conduct critical operations during the biological night; ground research demonstrates that certain properties of light can mitigate the risk of decreased performance related to these issues. Additionally, representatives from Human Factors and Habitability observed that the current brightness levels on ISS limit visual acuity and functional work space.

Representatives from BHP, Space Medicine, and Human Factors and Habitability have Therefore proposed technical specifications are being proposed for the replacement SSLAs that will allow the brightness and wavelengths of the lights to be modified depending on the operational need. Replacing the current ISS lights with these SSLAs will not only serve to improve visual acuity, but also allow for light's natural ability to effectively maintain astronauts' circadian rhythm with the Earth day-night cycle, has-

ten circadian shifting to facilitate schedule changes, improve alertness, and enhance performance.

Work is being done with the ISS vehicle board to implement an in-flight lighting system that will give crewmembers the ability to easily control lighting on the ISS and implement, for example, blue-enriched white light when a they need to adapt their circadian clock to Moscow time.

ISS Urine Monitoring System

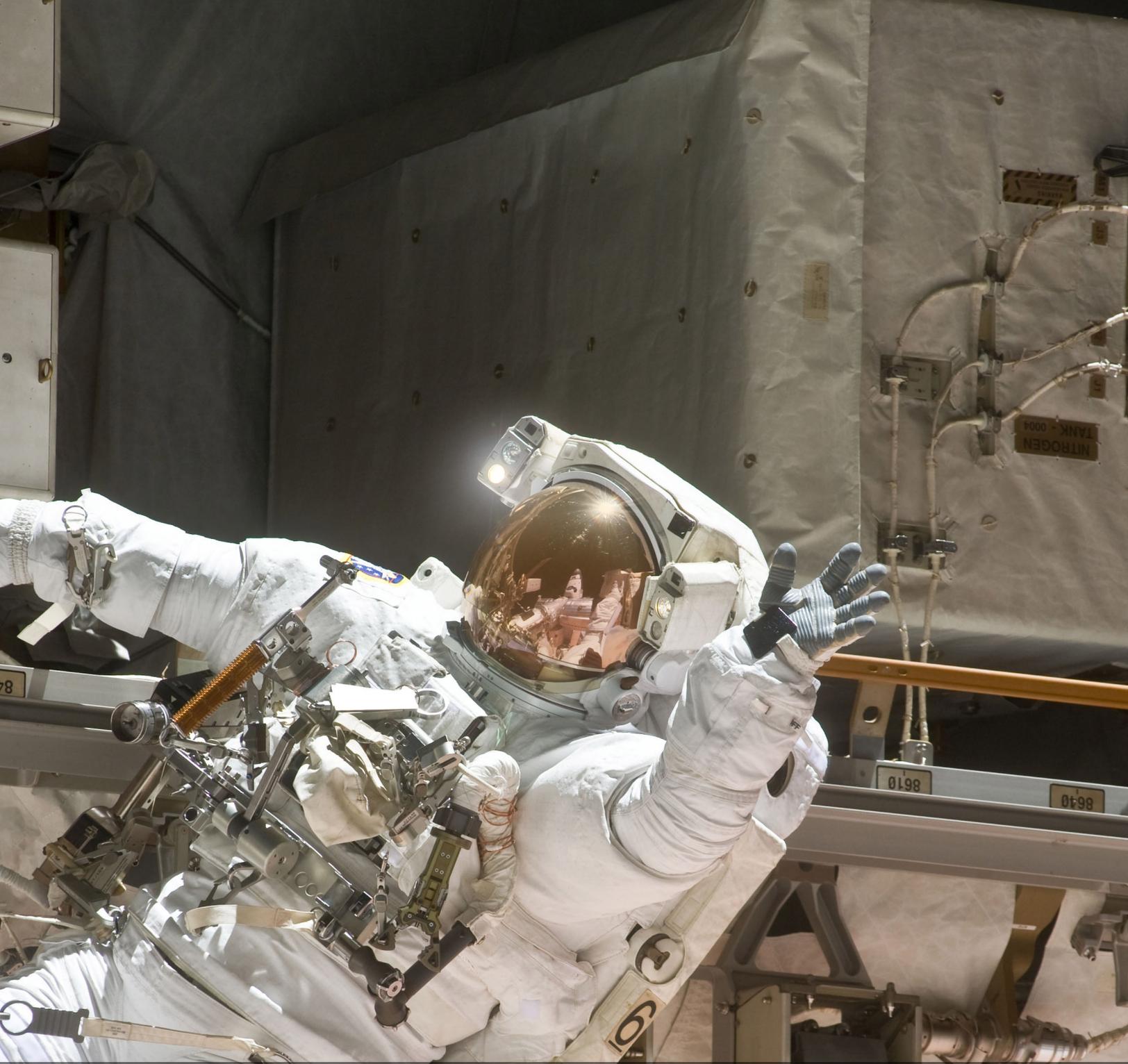
Collecting urine samples during flight enables the state of human physiology during space flight to be assessed non-invasively, provides information about the health of crewmembers, and is critical for validating countermeasures. The ISS Urine Monitoring System (UMS) was developed by NASA and is designed to collect an individual void, separate urine from air, accurately measure the volume of the urine, and allow urine samples to be acquired.



The Urine Monitoring System connects directly to the Waste and Hygiene Compartment and will facilitate the collection of urine samples for analysis.

The ISS UMS connects directly to the Waste and Hygiene Compartment and has positive impacts on crew time and convenience, up- and down-mass, and data collection. The UMS will support research investigations by facilitating the collection of urine samples for post-flight analysis.

The UMS was successfully certified for flight in 2010 and is scheduled for launch aboard STS-133. After delivery to the ISS, the hardware will be installed, validated, and finally integrated into human research investigations.



2010 Human Research Program Annual Report

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